Fundamentals of Robotics and Applications

(Course Code: BRA301)

Department of Robotics & Automation
JSS Academy of Technical Education, Bangalore-560060

Books

- S.R. Deb, Robotics Technology and flexible automation, Tata McGraw-Hill Education, 2009.
- Mikell P. Groover et al., "Industrial Robots - Technology, Programming and Applications", McGraw Hill, Special Edition, (2012).
- Ganesh S Hegde, “A textbook on Industrial Robotics”, University Science Press, 3rd edition, 2017.

Reference

- Richard D Klafter, Thomas A Chmielewski, Michael Negin, "Robotics Engineering – An Integrated Approach", Eastern Economy Edition, Prentice Hall of India Pvt. Ltd., 2006.
- Fu K S, Gonzalez R C, Lee C.S.G, "Robotics: Control, Sensing, Vision and Intelligence", McGraw Hill, 1987.

Further Learning

https://www.robots.com/applications

Course Learning Objectives (CLO)

- Understand the fundamental/elementary concepts of Robotics.
- Provide insight into different types of robots.
- Explain the intelligent module for robotic motion control.
- Educate on various path-planning techniques.
- Illustrate the working of innovative robotic devices.

Course outcomes (COs) (Course Skill Set)

At the end of the course, students will be able to,

CO1: Understand the significance, social impact and future prospects of robotics and automation in various engineering applications

CO2: Identify and describe the components and anatomy of the robotic system.

CO3: Categorise various types of robots based on their design and applications.

CO4: Know about various path planning techniques and analyze different motions of the robotics system

CO5: Use the suitable drives and end-effectors for a given robotics application.

CO6: Apply the robotics concept to automate monotonous and hazardous

Continuous Internal Evaluation (CIE)

- Assignment Component = 25 Marks
- Internal Assessment (IA) component = 25 Marks
- Two IA Tests, each of 25 Marks
- Two assignments each of 25 Marks
- For the course, CIE marks will be based on a scaled-down sum of two tests and other assessment methods.

The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50)

Semester End Examination(SEE)

- The question paper shall be set for 100 marks.
- The duration of SEE is 03 hours.
- The question paper will have 10 questions.
- 2 questions per module. Each question is set for 20 marks.
- The students have to answer 5 full questions, selecting one full question from each module.
- The student has to answer for 100 marks and **marks scored out of 100 shall be proportionally reduced to 50 marks**.

- *SEE minimum passing mark is 35% of the maximum marks (18 out of 50 marks).*
- *Students should secure a minimum of 40% (40 marks out of 100) in the sum total of the CIE and SEE taken together.*

Fundamentals of Robotics & Applications

MODULE 1: Introduction To Robotics

MODULE 1: Introduction To Robotics

Content

- Introduction To Robotics: Introduction to Robotics and Automation
- Laws of robots.
- Brief history of robotics, basic components of the robot, and robot specifications.
- Classification of robots, human systems and robotics.
- Safety measures in robotics, social impact.
- Robotics market and the future prospects.
- Advantages and disadvantages of robots.

Introduction

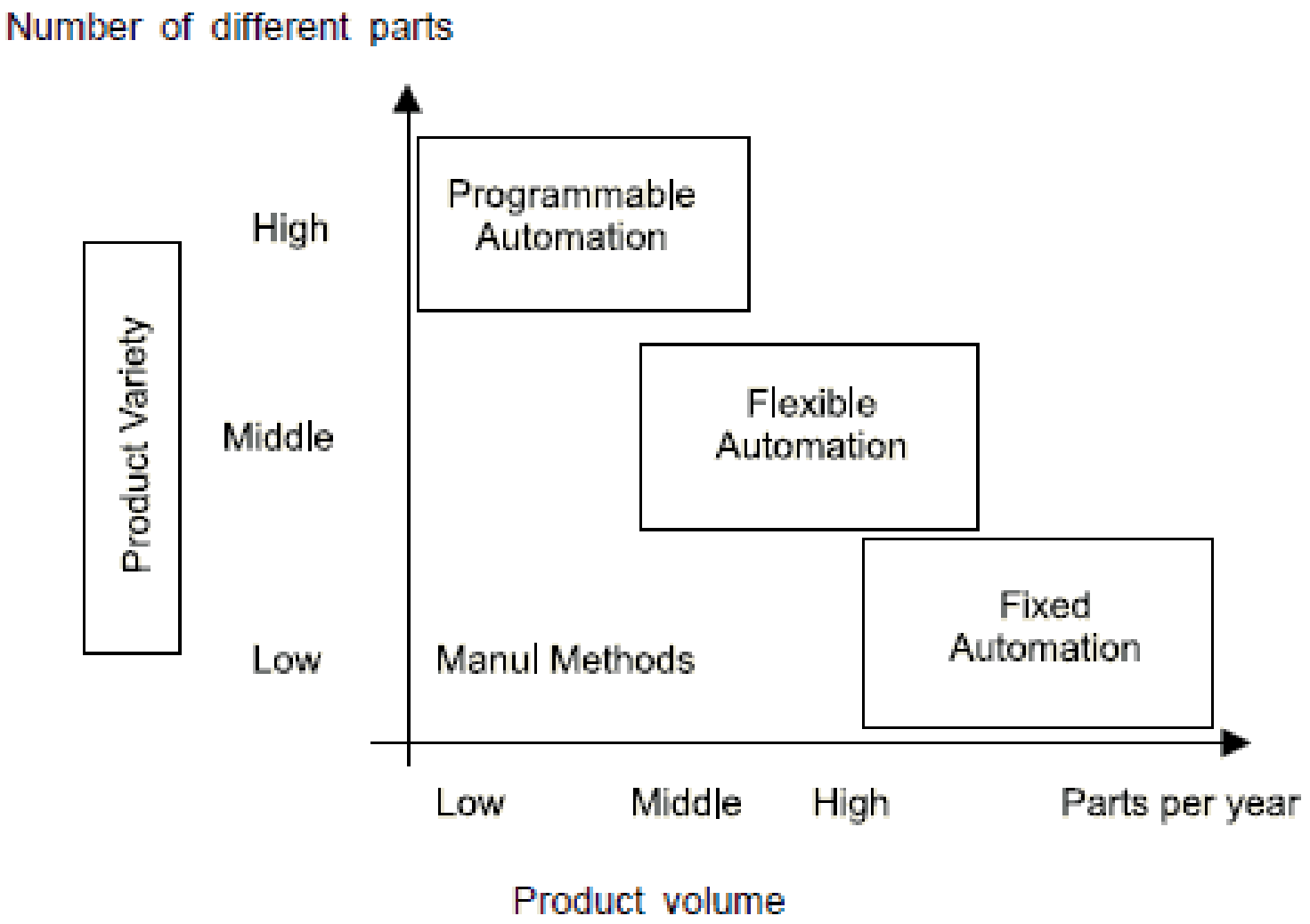
Difference between Robotics and Automation

- Robotics is the design, creation, and use of robots to perform tasks. These are physical robots that substitute for (or replicate) human actions.
- Robotics is a field that combines engineering and computer science to design and build robots to perform tasks.
- Automation as a technology concerned with the use of Mechanical, Electronic and Computer-based systems in the operation and control of Production.
- E.g. : Transfer lines, mechanised assembly machines, feedback control systems, NC Machine tools and robots

Introduction

Classification of Industrial Automation

1. Fixed Automation
2. Programmable Automation
3. Flexible Automation

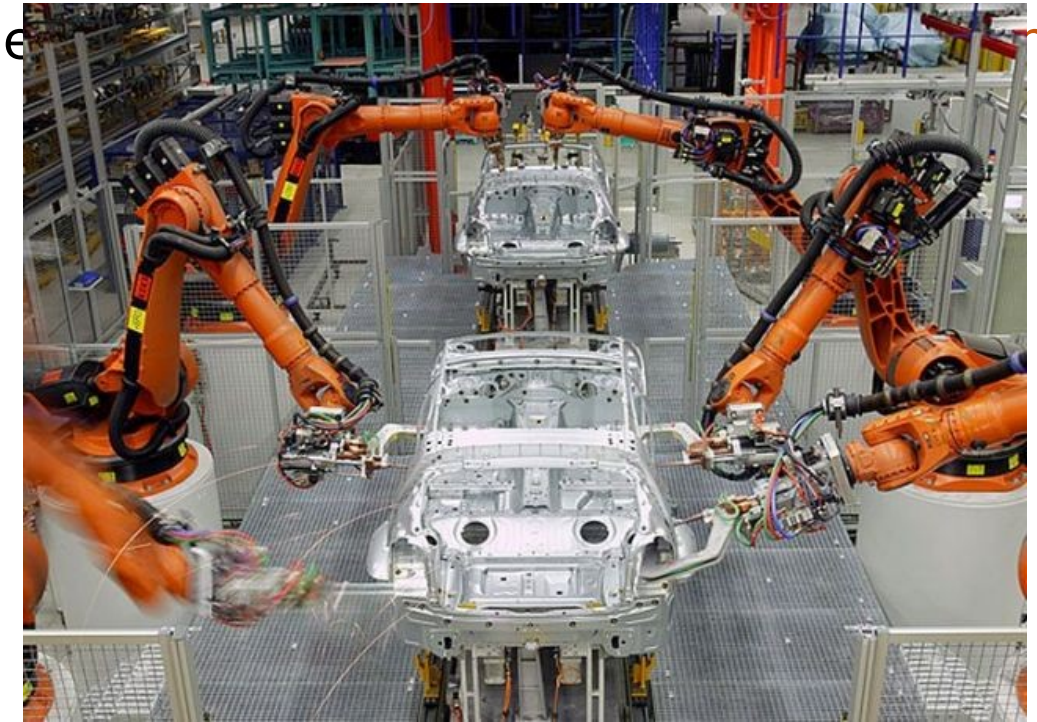


1. Fixed Automation / Hard Automation

- The sequence of processing is fixed for one particular product.
- Such a system can be used for mass production of a product.
- Initial cost is high, and any changes in product design can be incorporated with difficulty.
- If the product has to be changed, then a lot of modifications, new additions, etc., may be required, and to accommodate the me-consuming.

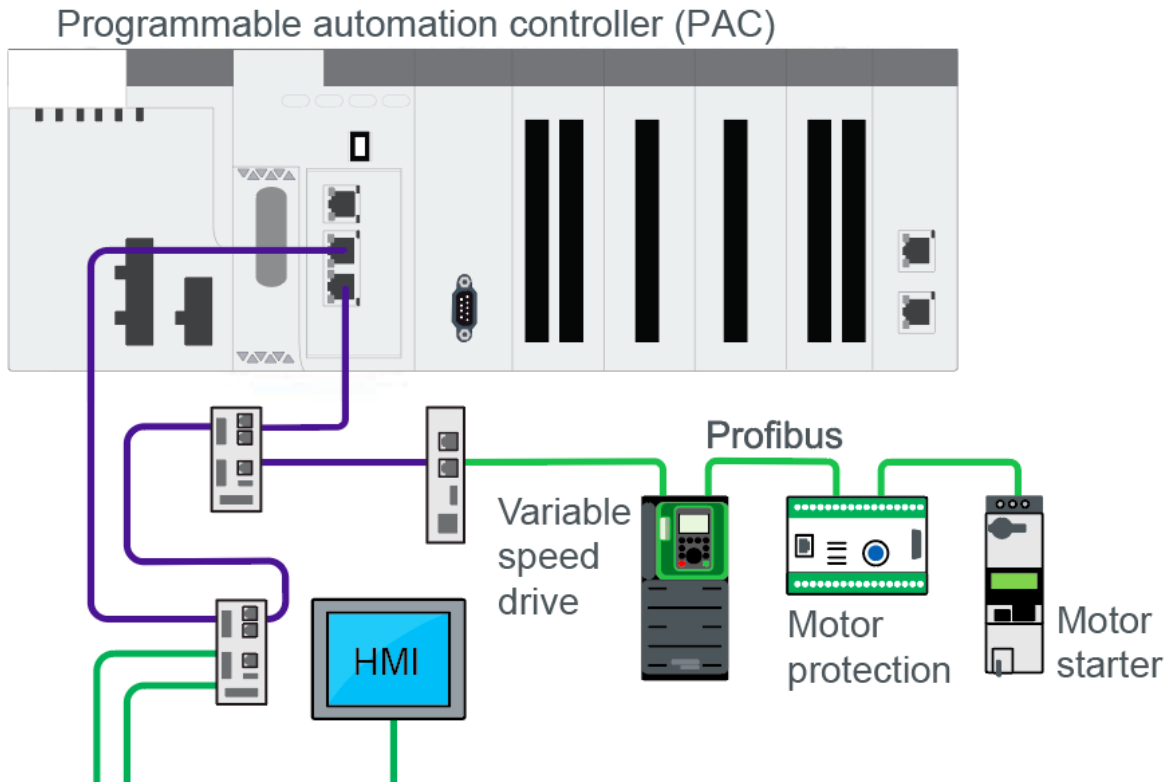
Examples

- *Automated assembly machines*
- *Chemical manufacturing processes*
- *Material handling conveyor systems*
- *Machining transfer lines*
- *Paint & coating automation processes*



2. Programmable Automation

- It is possible to accommodate the change in the sequence of operations for a new product by changing the program (set of instructions).
- Suited for batch production.
- For new products, programs, new tools and fixtures may have to be loaded and machine settings to be changed.
- Low volume products and variety proc



3. Flexible Automation

- Highly adaptable systems with computer input and controls.
- Commands are created and entered by human operators using computer code or through Human Machine Interfaces (HMIs).
- Multiple machine tools can be connected to a sophisticated material-handling system through robotic automation.
- A central computer system controls each aspect of the production and material-handling system.
- Ideal for batch processes and shops that have low-to-medium production level needs and high product-variety needs.

Example

Robotic arm used in a car assembly line can switch between tasks, such as welding, painting, or installing parts, depending on the car's specific model.

Definition of Industrial Robot

- The Robotic Industries Association (RIA) defines robot as follows:

"A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or special devices through variable programmed motions for the performance of various tasks."

- The industry's current working definition of a robot is "*any piece of equipment that has three or more degre*

Laws of Robots

The Three Laws of Robotics (The Three Laws or Asimov's Laws) are a set of rules devised by science fiction author Isaac Asimov, followed by robots in several of his stories.

1. First Law: A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. Second Law: A robot must obey the orders given by human beings except when that conflicts with the First Law.
3. Third Law: A robot must protect its own existence unless that conflicts with the First or Second Law.

ASIMOV'S THREE LAWS OF ROBOTICS STATE:

- Robots never harm Human Beings
- Robots must follow instructions from humans without violating rule 1
- Robots must protect themselves without violating the other rules

A HISTORICAL PERSPECTIVE OF ROBOTS

- The word robot was first used in 1921 by the Czech playwright, novelist, and essayist Karel Capek in his satirical drama entitled R.U.R. (Rossum's Universal Robots)
- It is derived from the Czech word *robota*, Which literally means "forced labourer or "slave labourer"
- Although Capek introduced the word "robot" to the world. The term "robotics" was coined by Isaac Asimov in his short story * Runaround." first published in 1942.
- This work is also notable because the so-called "Three Rules (or Laws) of Robotics" are presented for the first time:

Karel Čapek

Isaac Asim

A HISTORICAL PERSPECTIVE OF ROBOTS

GENERATIONS OF ROBOT

First Generation

- Non-servo, pick-and-place or point-to-point robots are classified as 1st gen. robots.
- The technology is fully developed.
- Predicted that these will continue to be in use for another 20 years.

Second Generation

- Addition of sensing devices and enabling the robot to alter its movements in response to sensory feedback
- These robots exhibit path control capabilities

Third Generation

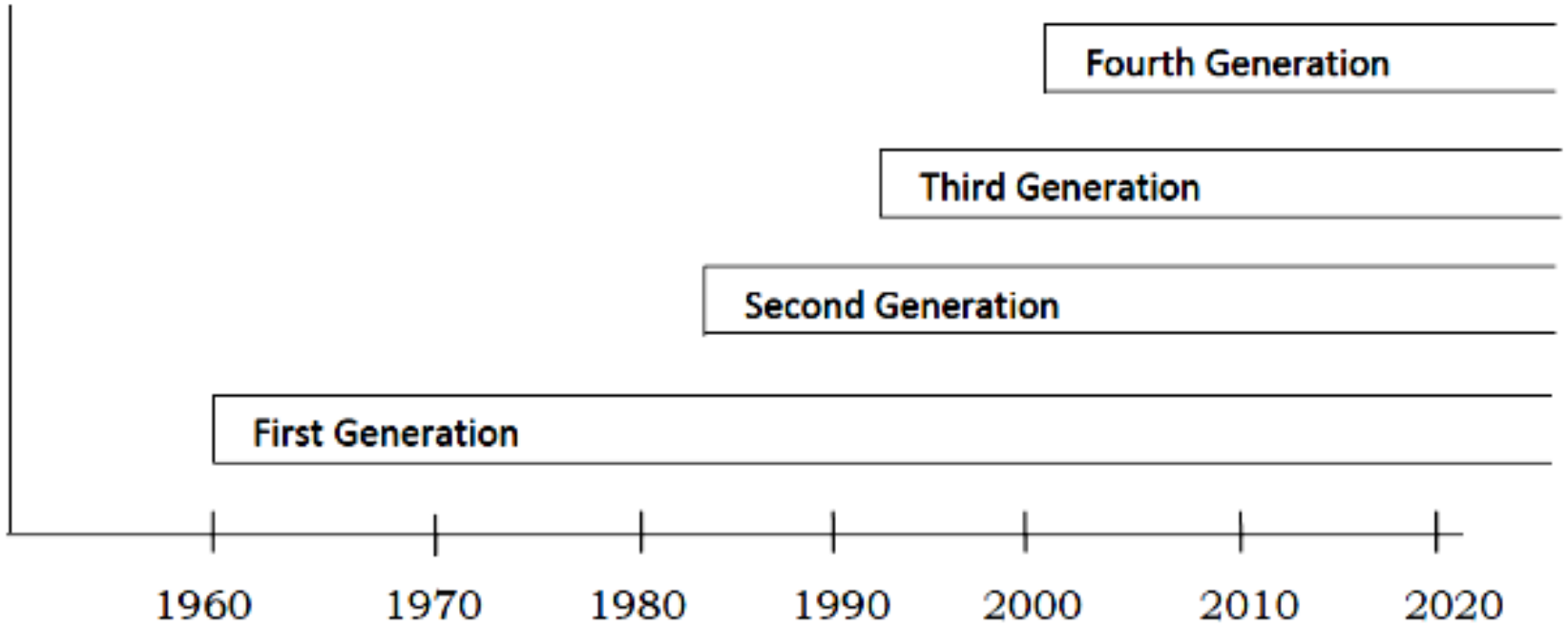
- Robots with a brain having intelligence.
- Robots acquired AI, self-learning and conclusion drawing capabilities by past experiences.
- On-line computations and control, artificial vision and active force/torque interaction with the environment are characteristics of

A HISTORICAL PERSPECTIVE OF ROBOTS

GENERATIONS OF ROBOT

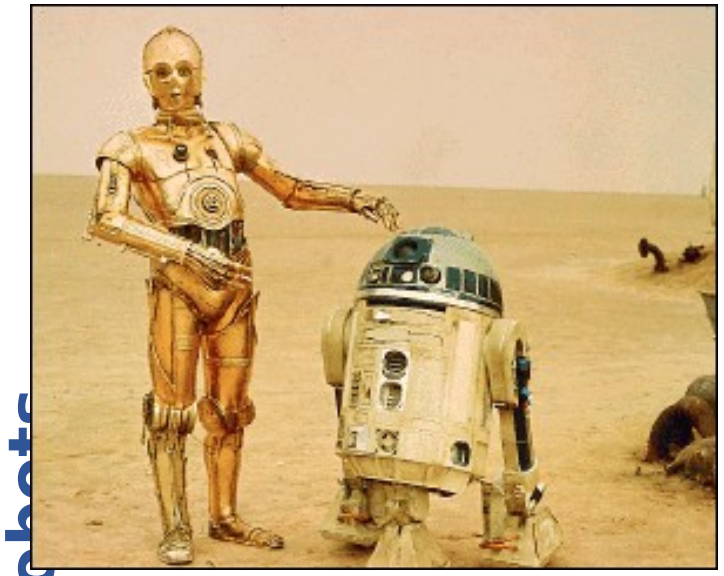
Fourth Generation

- This is futuristic and may be a reality only in the current millennium
- Prediction about its features is difficult
- True android or an artificial biological robot or a super humanoid robot of producing its own clones.



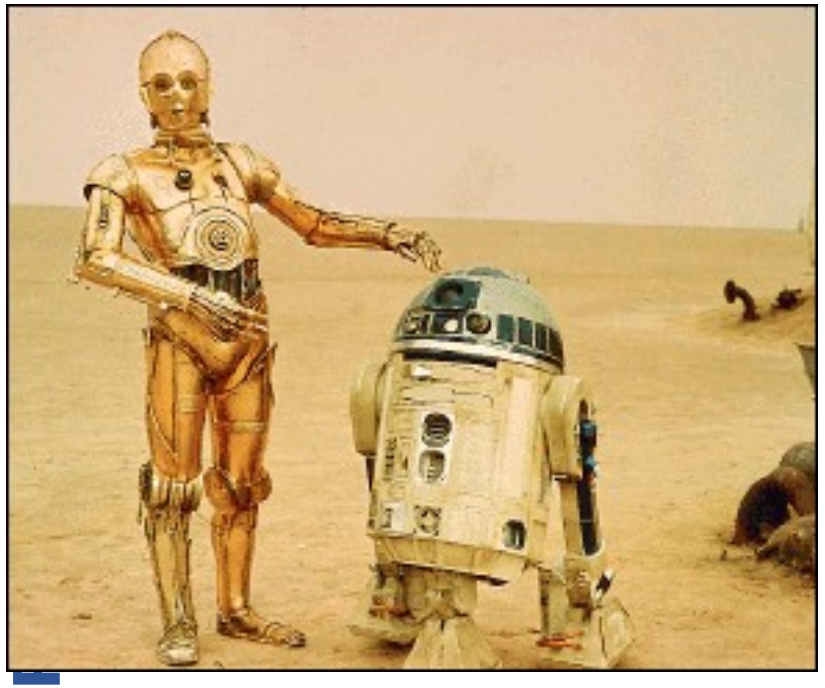
A pictorial representation of overlapping generations of robots

Brief History of Robots



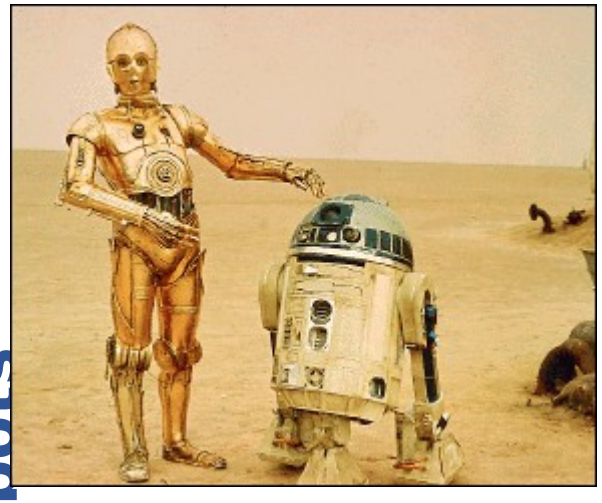
Date	Development
mid-1700s	J. de Vaucanson built several human-sized mechanical dolls that played music.
1801	J. Jacquard invented the Jacquard loom, a programmable machine for weaving threads or yarn into cloth.
1805	H. Maillardet constructed a mechanical doll capable of drawing pictures.
1946	American inventor G. C. Devol developed a controller device that could record electrical signals magnetically and play them back to operate a mechanical machine U.S. patent issued in 1952.
1951	Development work on teleoperators (remote-control manipulators) for handling radioactive materials. Related U.S. patents issued to Goertz (1954) and Bergsland (1958),
1952	Prototype Numerical Control machine demonstrated at the Massachusetts Institute of Technology after several years of development. Pan programming language called APT (Automatically Programmed Tooling) subsequently developed and released in 1961,
1954	British inventor C. W. Kenward applied for patent tor robot design. British patent issued in 1957.
1954	G. C. Devol develops designs for "programmed article transfer." U.S. patent issued tor design in 1961,
1959	First commercial robot introduced by Planet Corporation. It was controlled by limit switches and cams.

Brief History of



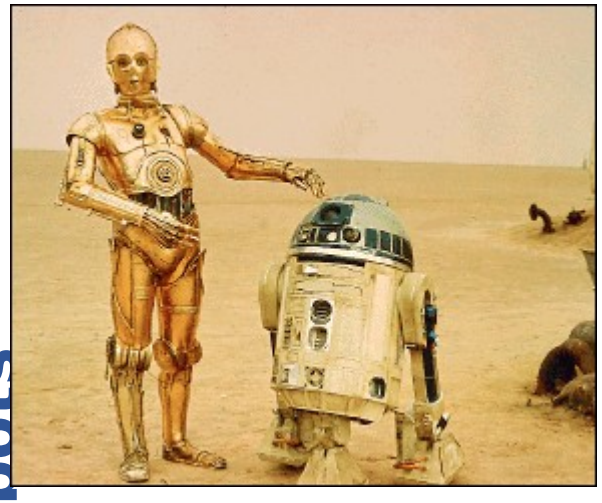
1960	First "Unimate" robot introduced, based on Devol's "programmed ankle transfer." It used numerical control principles for manipulator control and was a hydraulic drive robot.
1961	Unimate robot installed at Ford Motor Company for tending a die casting machine.
1966	Trallfa, a Norwegian firm, built and installed a spray painting robot.
1968	A mobile robot named "Shakey" developed at SRI (Stanford Research Institute). It was equipped with a variety of sensors, including a vision camera and touch sensors, and can move on the floor.
1971	The "Stanford Arm," a small electrically powered robot arm, developed at Stanford University.
1973	First computer-type robot programming language developed at SRI for research called WAVE Followed by the language AL in 1974. The two languages were subsequently developed into the commercial VAL. language for Unimation by Victor Scheinman and Bruce Simano.
1974	ASEA introduced the all-electric drive IRb6 robot.
1974	Kawasaki, under Unimation license, installed arc-welding operation for motorcycle frames.
1974	Cincinnati Milacron introduced the T3 robot with computer control.
1975	Olivetti "Sigma" robot used in assembly operation–one of the very first assembly applications of robotics.
1976	Remote Center Compliance (RCC) device for part insertion in assembly developed at Charles Stark Draper Labs in United States.
1978	PUMA (Programmable Universal Machine for Assembly) robot introduced for assembly by Unimation, based on designs from a General Motors study.

Brief History of Robots



1978	Cincinnati Milacron T3 robot adapted and programmed to perform drilling and routing operations on aircraft components, under Air Force ICAM (Integrated Computer-Aided Manufacturing) sponsorship.
1979	Development of SCARA type robot (Selective Compliance Arm for Robotic Assembly) at Yamanashi University in Japan for assembly. Several commercial SCARA robots introduced around 1981.
1980	Bin-picking robotic system demonstrated at University of Rhode Island. Using machine vision, the system was capable of picking parts in random orientations and positions out of a bin.
1981	A “direct-drive robot” developed at Carnegie-Mellon University. It used electric motors located at the manipulator joints without the usual mechanical transmission linkages used on most robots.

Brief History of Robots



1982	IBM introduces the RS-1 robot for assembly, based on several years of in-house development. It is a box-frame robot, using an arm consisting of three orthogonal slides. The robot language AML, developed by IBM, also introduced to program the RS-1.
1983	Report issued on research at Westinghouse Corp under National Science Foundation sponsorship on "adaptable-programmable assembly system" (APAS), a pilot project for a flexible automated assembly line using wools.
1984	Several off-line programming systems demonstrated at the Robots 8 show. Typical operation of these systems allowed the robot program 10 he developed using interactive graphics on a personal computer and then downloaded to the robot.
1990's	Robot development diversified into walking robots at MIT, Honda, etc., rehabilitation robots for health care, as well as robots for defense and space applications.
2000's	Micro and nano robots using smart materials, Unmanned Ariel vehicles and underwater robotics.

A Brief History of Robotics

One Hundred Years Since Robots were First Imagined

INFO@CAPITALXPARTNERS.CO

1921 — The term "Robot" is coined by Czech playwright Karel Capek.

1961 — General Motors installs its first Unimate Robot

1985 — First Robot-assisted surgery

1988 — First AI Chatbot

1997 — IBM Deep Blue beats world chess champion Garry Kasparov

1997 — NASA pathfinder Lands on Mars

1999 — Sony launches Aibo, an AI powered Robo dog

2003 — Industrial Robot Population surpasses 1m units

2010 — Apple Introduces Siri

2012 — Amazon.com $750m Acquisition of KIVA Systems

2017 — Industrial Robot Population surpasses 2m units

2020 — Industrial Robot Population surpasses 3m units

1980 1990 2000 2010 2020

First Generation

1954 — George Devol Jr Develops Unimate, the first digitally programmable Robot.

1968 — Shaky the first Mobile Robot

Second Generation

1981 — Scara Robot

1988 — Helpmate, the first Mobile Robot for hospitals.

Third Generation - Advanced Robots

2001 — da Vinci Surgery Approved by the FDA

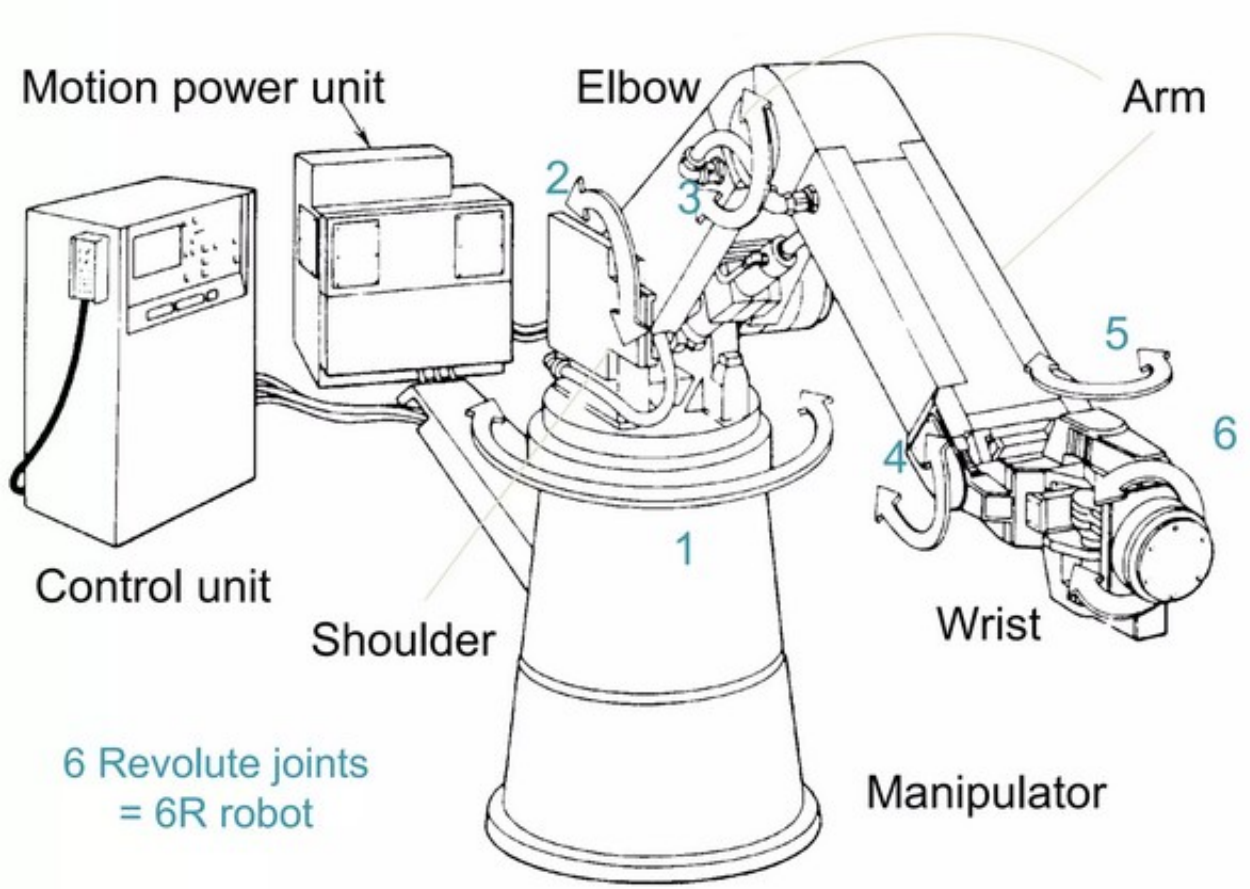
2002 — iRobot Launches Roomba cleaning bot

2013 — rethink robotics Launches the first co-bot, Baxter.

Robot Development Phases

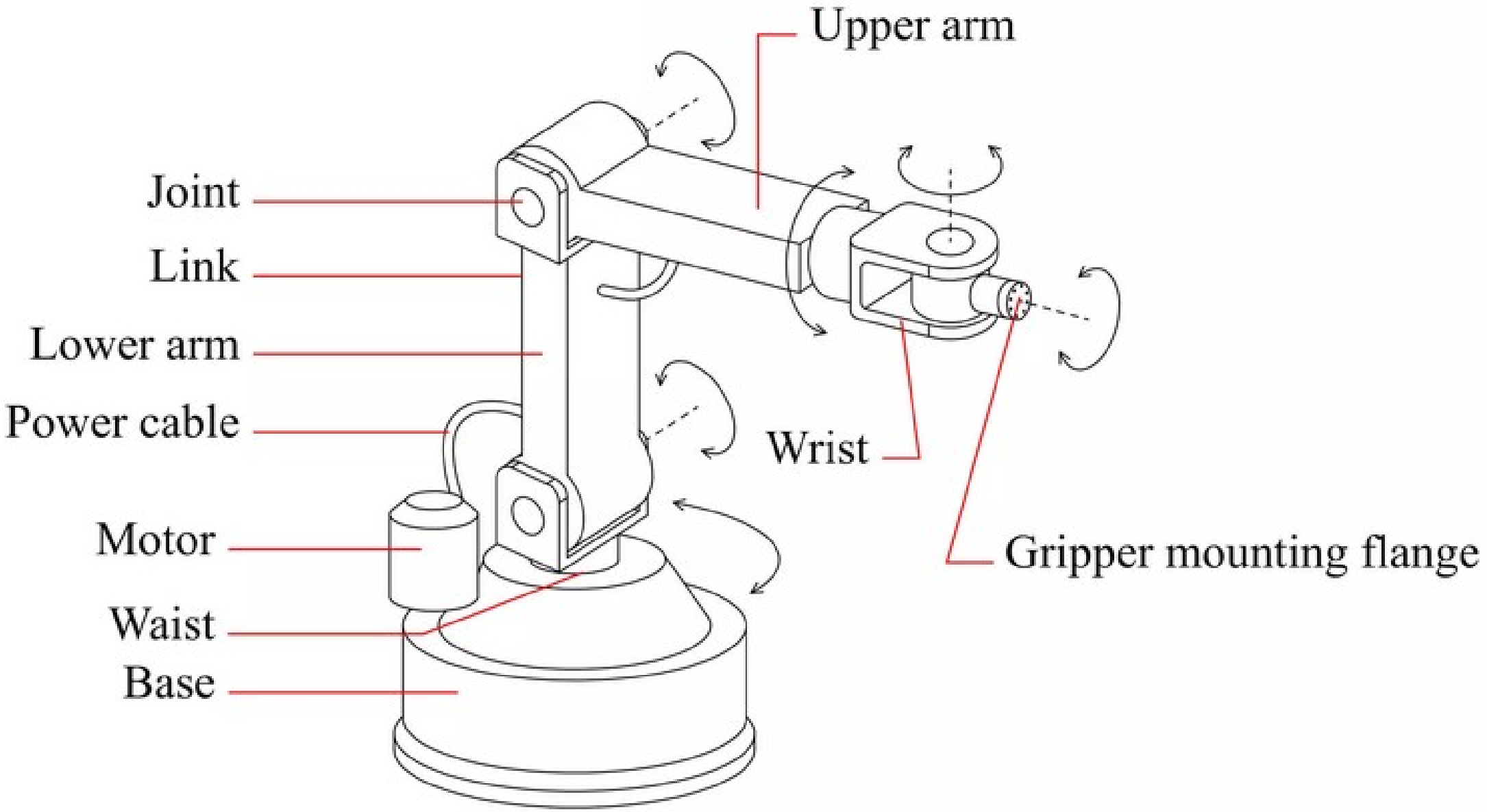
Year	Developments
1950-1970	Simple pick and place robots controlled by computers with limited interaction
1980-1990	Interaction with the environment using force, touch sensors, vision
1999-2000	Intelligent robots
2000-present	Micro, nano, robots, bio-robots humanoids, service robots
Future robots	Personal robots, professional robots

Basic components of Robot

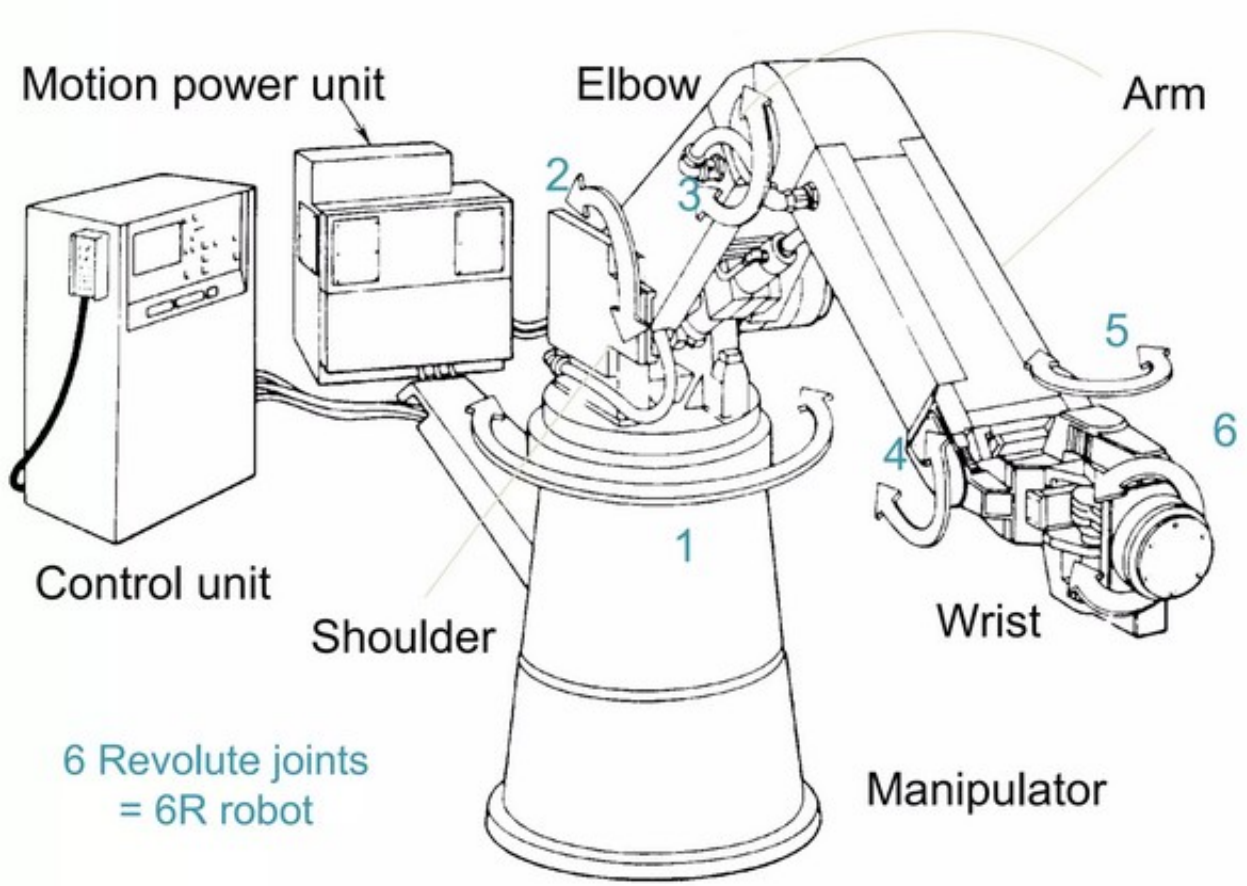


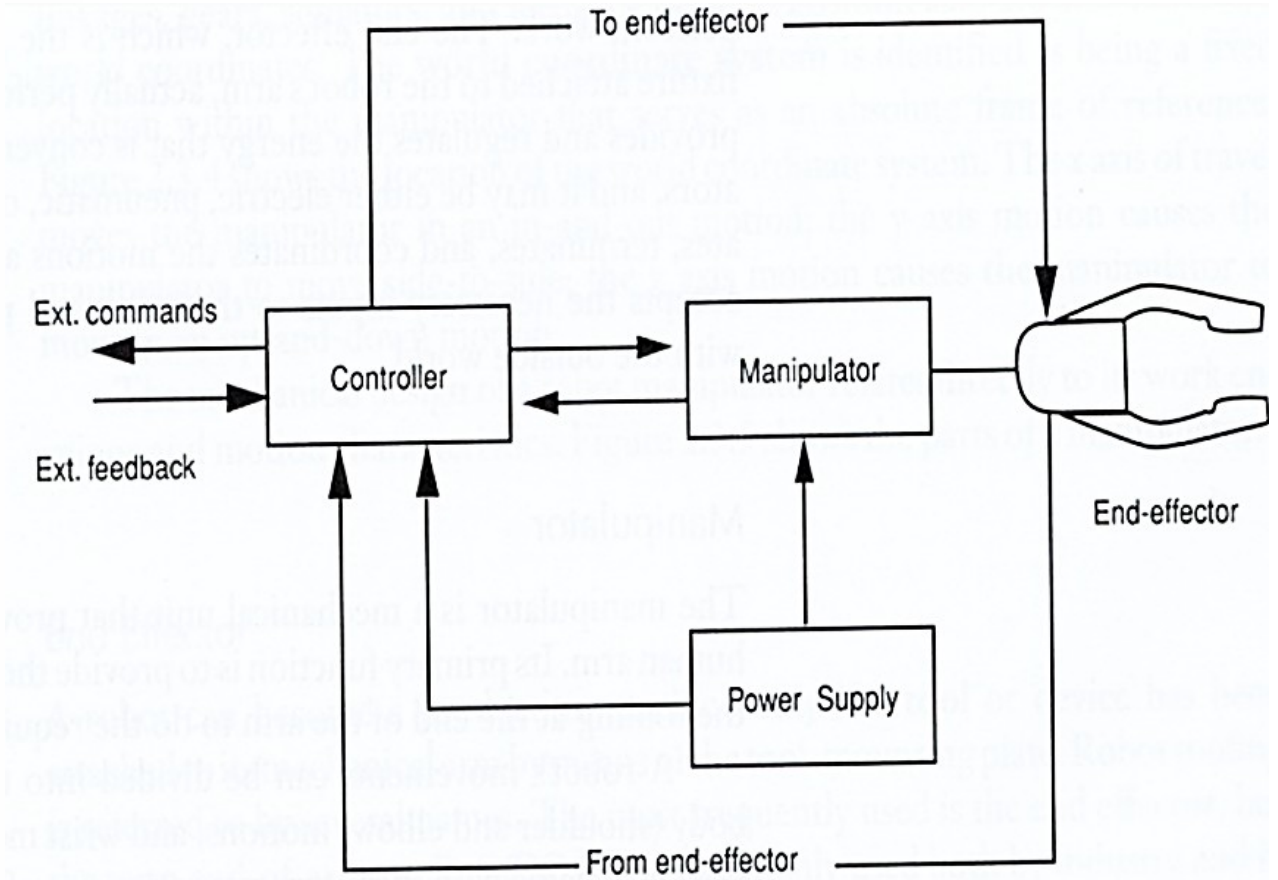
The four major components of a robot are;

1) Manipulator or arm (the "mechanical unit")
2) One or more sensors
3) Controller (the "brain")
4) Power supply

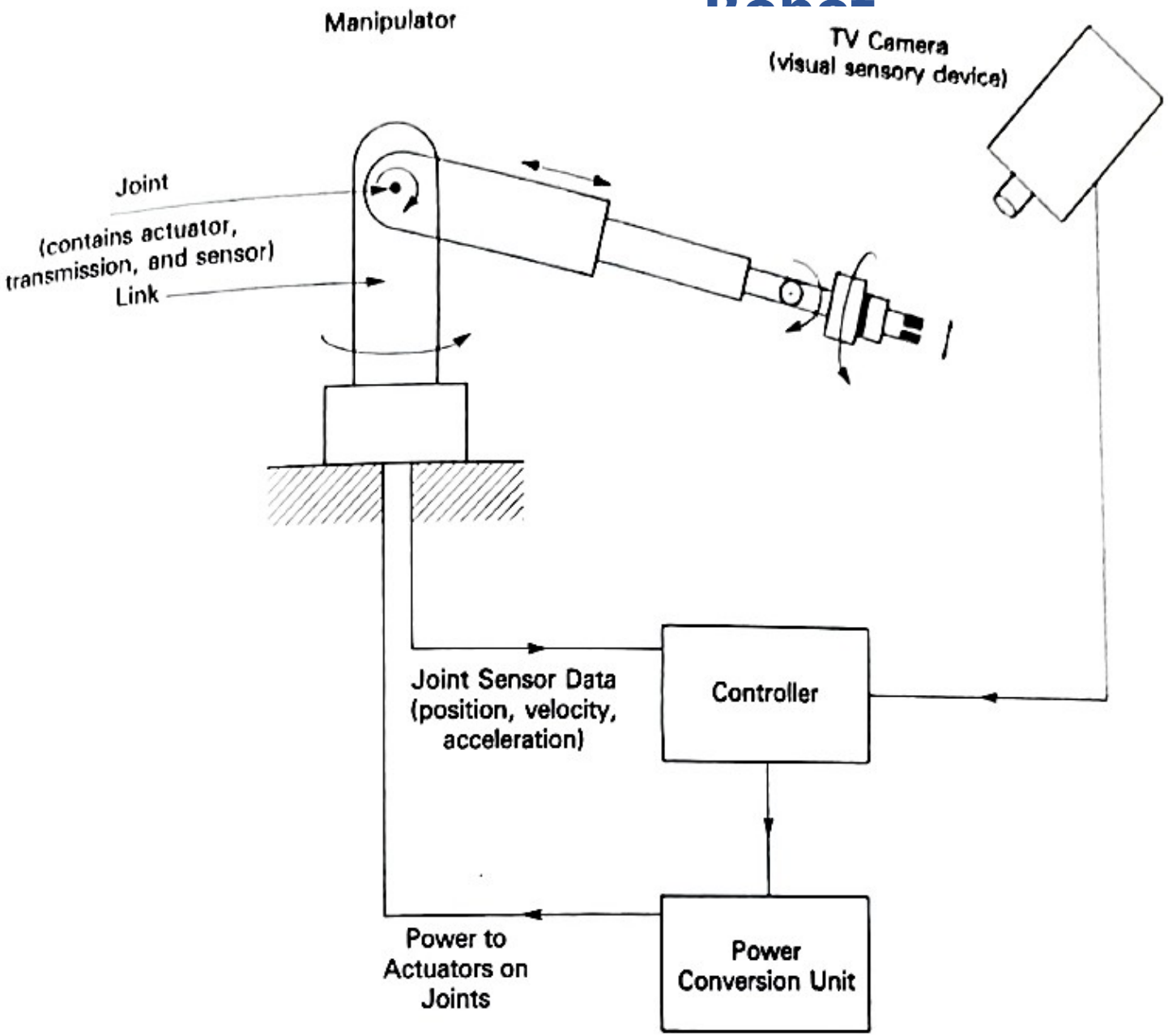

Upper arm
Joint
Link
Lower arm
Power cable
Wrist
Motor
Gripper mounting flange
Waist
Base

Basic components of Robot





Basic components of Robot



Basic components of Robot

1. Manipulator or arm (the "mechanical unit")

Manipulator defined by the joint-link structure, has three main structural elements: the arm, the wrist, and the hand (or end effector).

- Robot need to manipulate objects: pickup, place, hold, etc.
- Hands of robot are referred as end effectors (end of robotic arm)
- Robot Arm is referred as manipulator
- End effectors are the tools at the end of robotic arms, directly interact with objects.

Robot end effector

Basic components of Robot

2. Sensors

- Sensors: allow robot to gather information about its environment.
- Sensors allow robotic arm to receive feedback about its environment

E.g., Camera, Vision sensor, Microphones, Thermometers, LIDAR (light detection and ranging

Sensors used in modern robots can be divided into two general classes.

1. Nonvisual: limit switches (e.g., proximity, photoelectric or mechanical), position sensors (e.g., optical encoders, potentiometers) velocity sensors (e.g., tachometers), or force and tactile sensors (for overload protection, path following, calibration, part recognition, or assembly work).
2. Visual: TV cameras coupled to appropriate image-detection hardware.

Basic components of Robot

3. Controller

Robot controllers generally perform three functions;

1. They initiate and terminate the motion of the individual components of the manipulator in a desired sequence and at specified points.
2. They store position and sequence data in their memory.
3. They permit the robot to be interfaced to the "outside" world via sensors

- To carry out these tasks, controllers must perform the arithmetic computations for determining the correct manipulator path, speed, and position.
- They must also send signals to the joint-actuating devices (via interfaces) and utilize the information provided by the robot's sensors.
- They must permit communication between peripheral devices and the manipulator.

Basic components of Robot

4. Power Supply

- Provide the necessary energy to the manipulator's actuators.
- It can take the form of a power amplifier in the case of servomotor-actuated systems, or a remote compressor when pneumatic or hydraulic devices are used

Robot Classification

According to Japanese Industrial Robot Association (JIRA)	According to Association Francaise de Robotique (AFR)
Class 1: Material Handling device: Man operated multiple degree of freedom machine used for handling	**Type A:** Manual Handling devices
Class 2: Fixed Sequence Robot Robots performing unchangeable pre determined stages of work in a sequence	**Type B:** Automatic handling devices with fixed cycles
Class 3: Variable Sequence robots: Same as class 2, the sequence can be easily altered	**Type C:** Programmable with point to point or continuous path controlled by servo motors
Class 4: Playback robot: The motions are taught by operator which is recorded and then the path is followed by robot	**Type D:** Programmable intelligent robots that can work gathering information from the surrounding
Class 5: Numerically controlled Robot The operations are programmed by the operator using APT and given to robot	
Class 6: Intelligent robots: these can understand tasks in a surrounding and act intelligently	

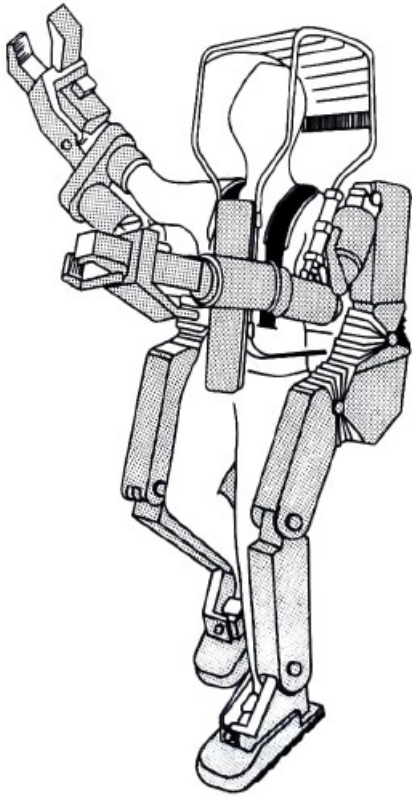
Robot Classification

1. Prostheses

- Often referred to as "robot arms" or "robot legs".
- They can make use of either hydraulic or servomotor actuators.
- Utilize servo control, and have mechanical linkages.
- They do not have their own brains and are not programmable.

2. Exoskeletons

- These are a collection of mechanical linkages that are made to surround either human limbs or the entire human frame.
- They have the ability to amplify a human's power
- They cannot act independently and, as such, are not robots.
- When Exoskeletal device is used, the operator must exercise extreme caution due to the increased forces and/or speeds that are possible

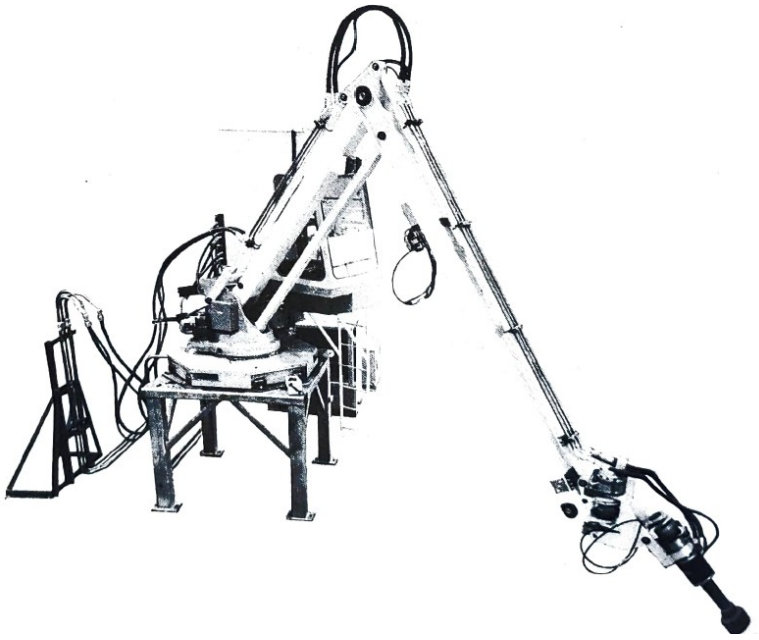


General Electric Hardiman, an exoskeletal device developed in the 1970s. It allowed a human operator to lift loads up to 1500 lbs, and utilized hydraulically actuated servos.

Robot Classification

3. Telecherics

- These devices permit manipulation or movement of materials and/or tools that are located many feet away from an operator
- Telecheric mechanisms use either hydraulic or servo actuators, which are usually controlled in a closed-loop manner, they are not robots, because they require a human being to control and to make decisions about position and speed.
- Such devices are useful in deal such as radioactive waste

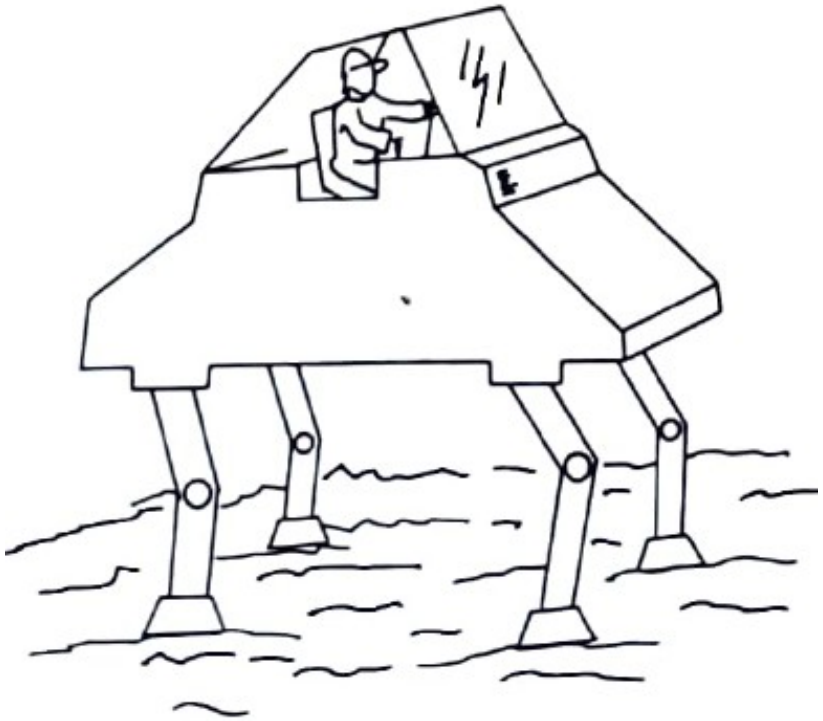


G.E. Manmate Industrial Manipulator is an articulating arm boom that can be used for material handing

Robot Classification

4. Locomotive Mechanisms

- These are devices that imitate human beings or animals by having the ability to walk on two or four legs.
- Linkages are hydraulically or electrically actuated under closed-loop control, a human operator is still required to execute the locomotive process



- *The General Electric four-legged walking machine.*
- *Because of severe stability problems, the project was never*

Robot Classification

Classification by Coordinate System / Physical configuration

- The mechanics of a robotic manipulator (arm-like structure) can vary considerably.
- The major axes of the device, consist of the two or three joints or degrees of freedom (DOF)

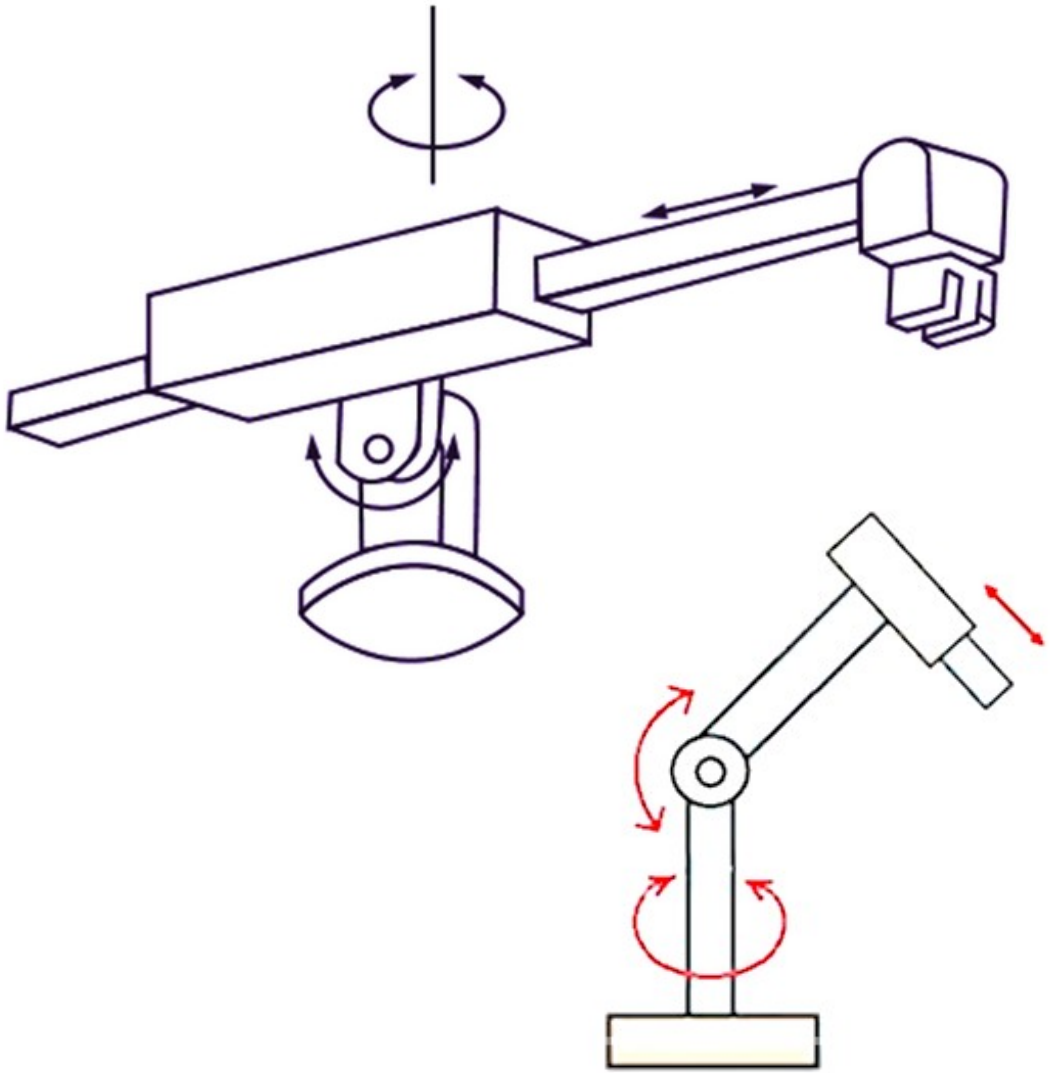
Today's commercially available robots possess four basic configurations;

1. Polar Configuration
2. Cylindrical configuration
3. Cartesian coordinate configuration
4. Jointed arm robots

Robot Classification

Classification by Coordinate System

1. Polar / Spherical Configuration



- This combination allows the robot to operate in a spherical work volume.

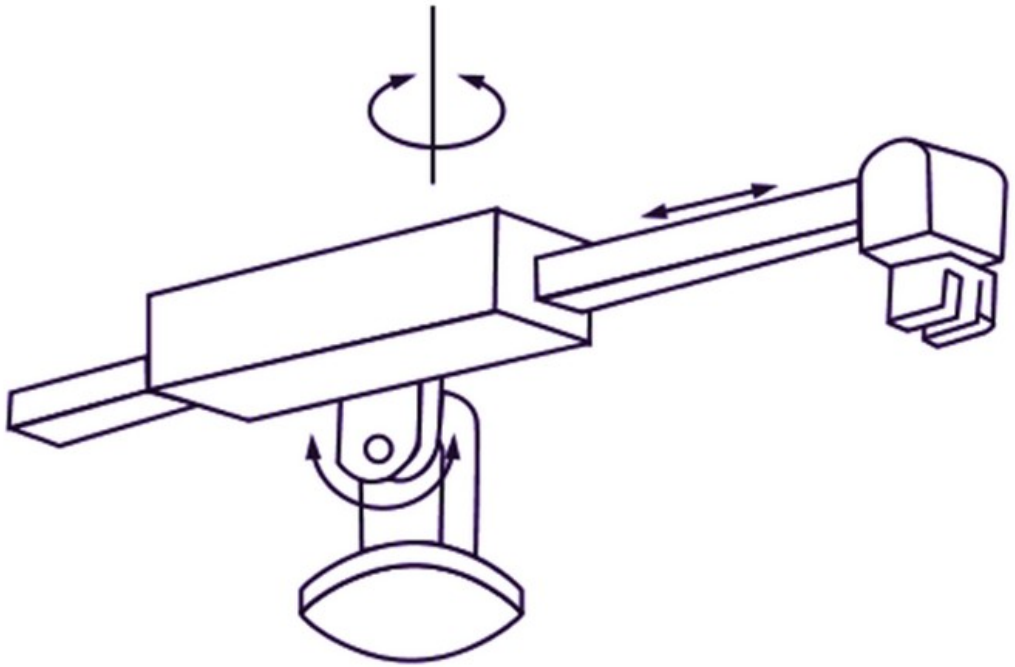
The robot arm has following movements.

1. **Linear movement**: allows the arm to extend and retract because of one linear joint.
2. Rotary movement: occurs around an axis (vertical) perpendicular to the base because of one twisting joint.
3. Vertical lift of the arm about the pivot point because of one rotational joint.

Robot Classification

Classification by Coordinate System

1. Polar / Spherical Configuration



Advantages

- Long reach capabilities in horizontal position
- Good lifting capabilities
- Suitable for small amount of vertical applications

Limitations

- Low vertical reach
- Reduced mechanical rigidity

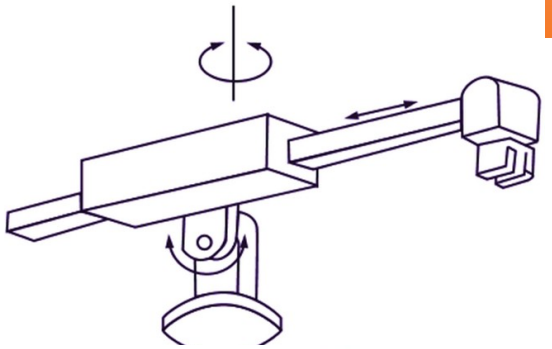
Applications: Machine loading, Material movement, stacking of components, Heat treatment operations

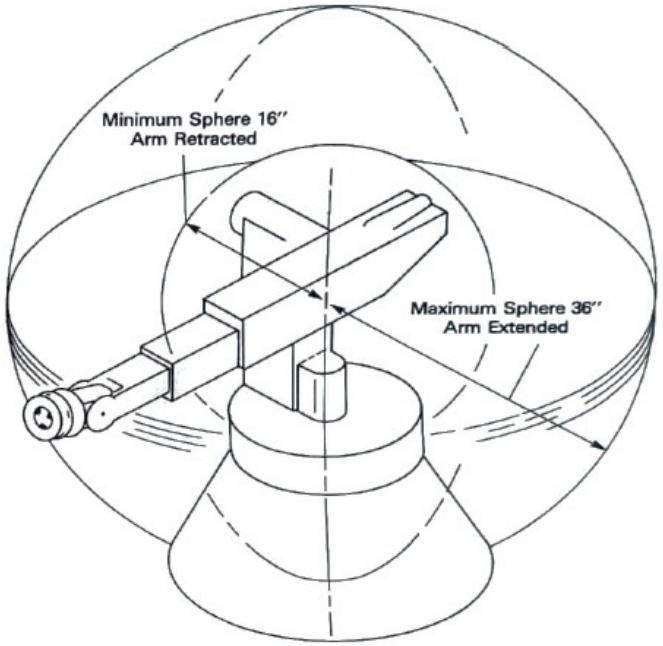
Ref: https://electricalworkbook.com/polar-robot/

Robot C

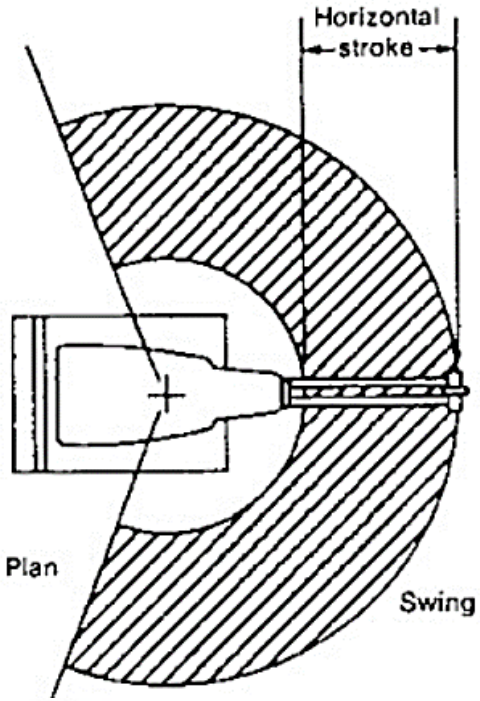
Classification by Coordinate System

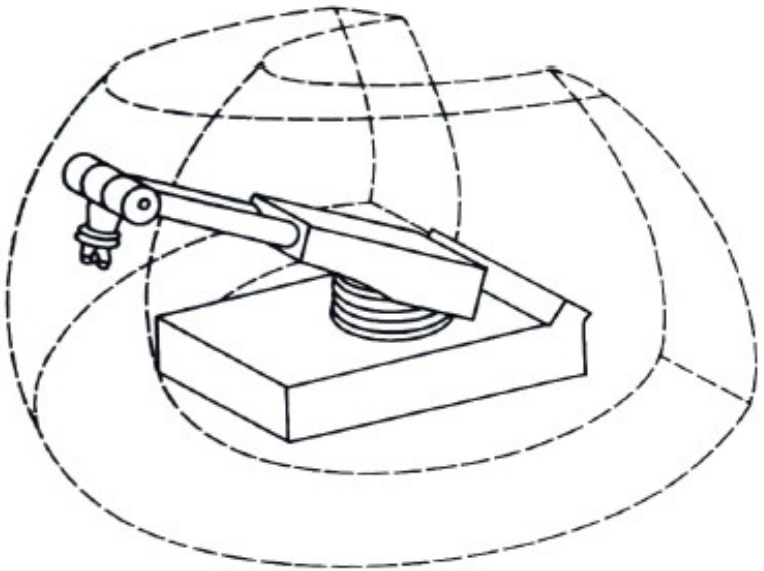
1. Polar / Spherical Configuration



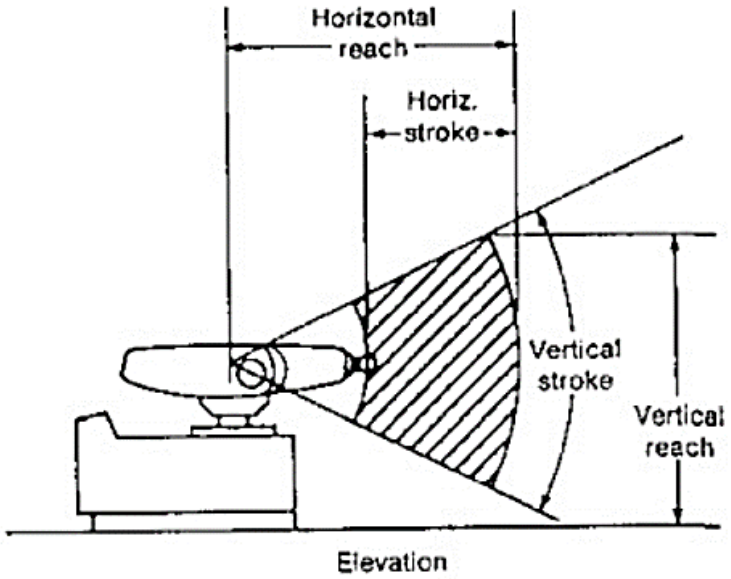


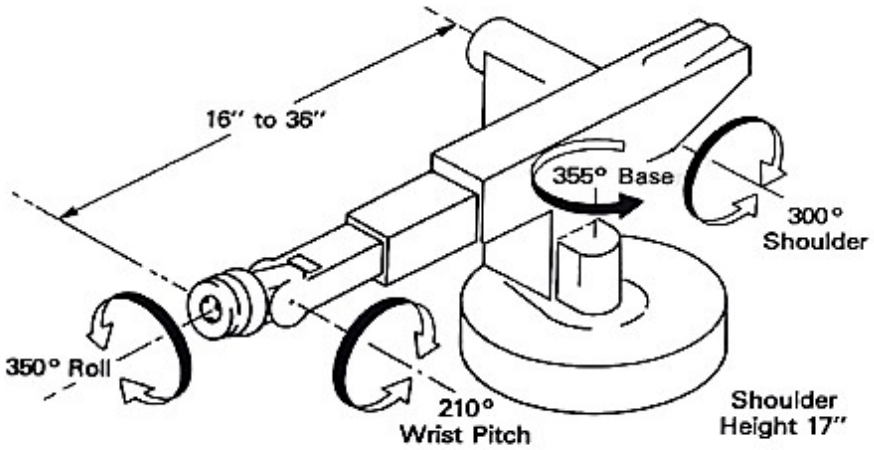
Workspace of robot / Work





Geometry of robot major



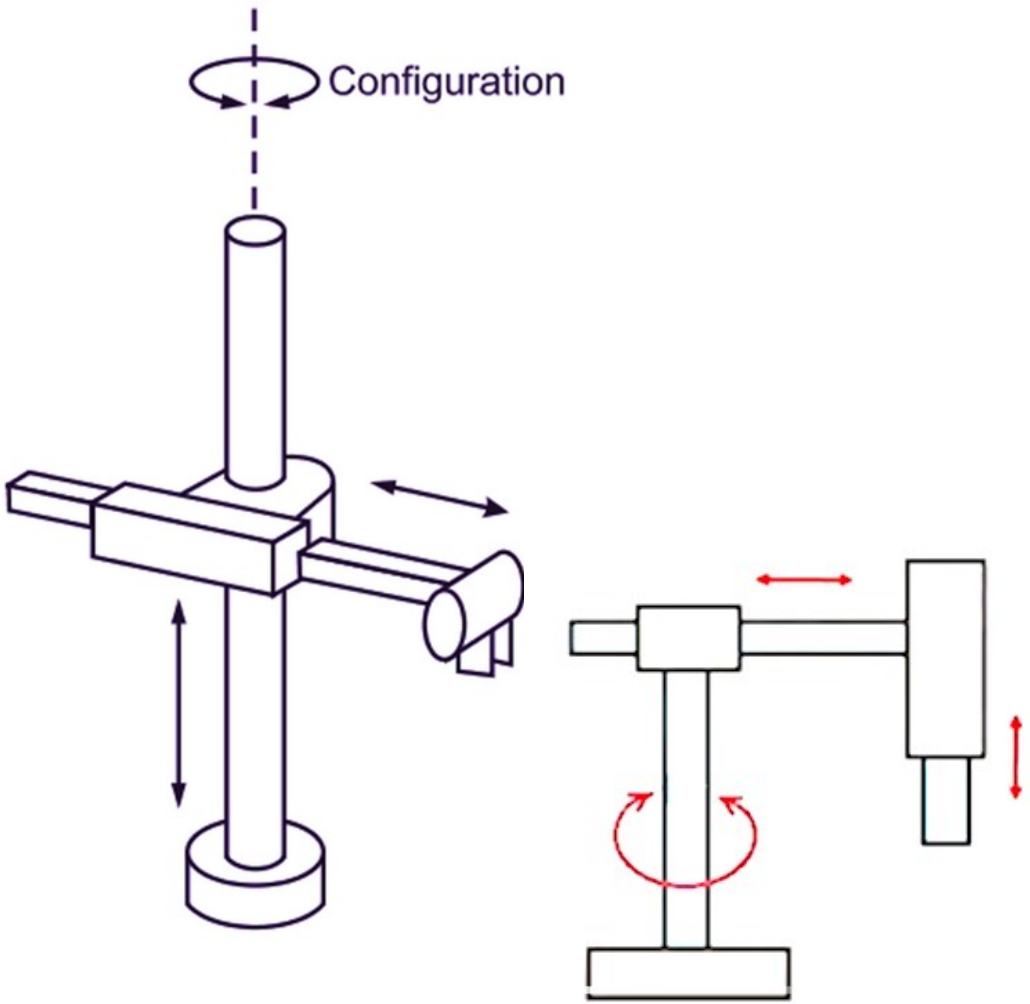


Range of Motion (c)

Robot Classification

Classification by Coordinate System

2. Cylindrical Configuration



- This combination allows the robot to reach work space in a rotary movement like a cylinder

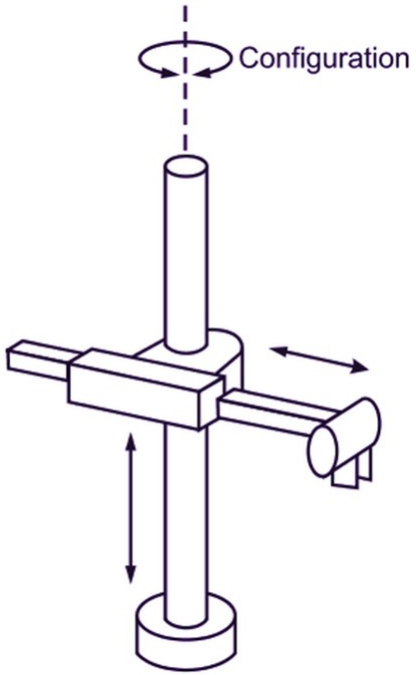
The robot arm has following movements.

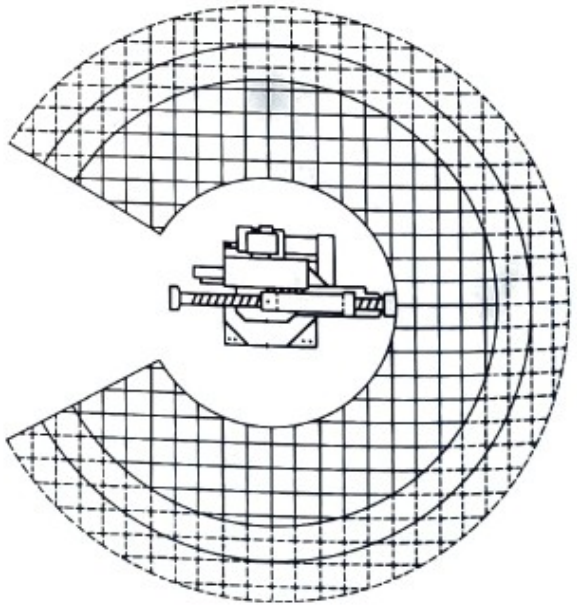
1. **Rotational movement**: of the column about its axis because of one twisting joint
2. Linear movement: of the assembly along the column because of one linear joint
3. Linear movement in and out, relative to the column axis because of one orthogonal joint

Robot Classification

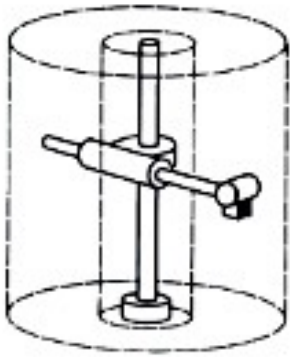
Classification by Coordinate System

2. Cylindrical Configuration





Workspace of robot / Work volume



Geometry of robot major axis

Advantages

- Higher load carrying capacity
- Provides high rigidity to the manipulator
- Suitable for pick and place applications

Limitations

- Require more floor space
- Reduced mechanical rigidity because rotary axis must overcome inertia of the object when rotating

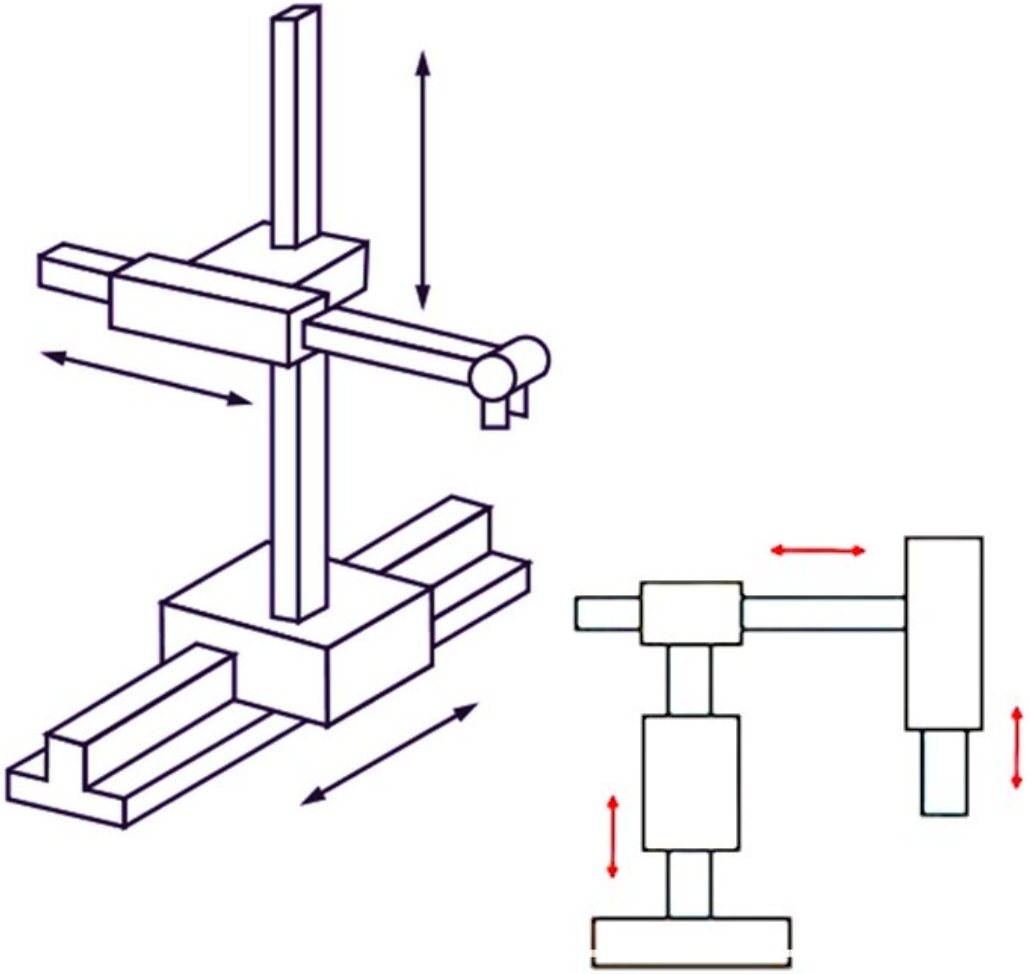
Applications: Conveyor pallet transfer, machine tool loading, forging , packing, precision small assembly etc.

Ref: https://electricalworkbook.com/cylindrical-robot/

Robot Classification

Classification by Coordinate System

3. Cartesian Coordinate Configuration



- Also referred as Rectilinear robot or X-Y-Z robot of the spherical configuration, as it is equipped wit three sliding joints.

The robot arm has following movements.

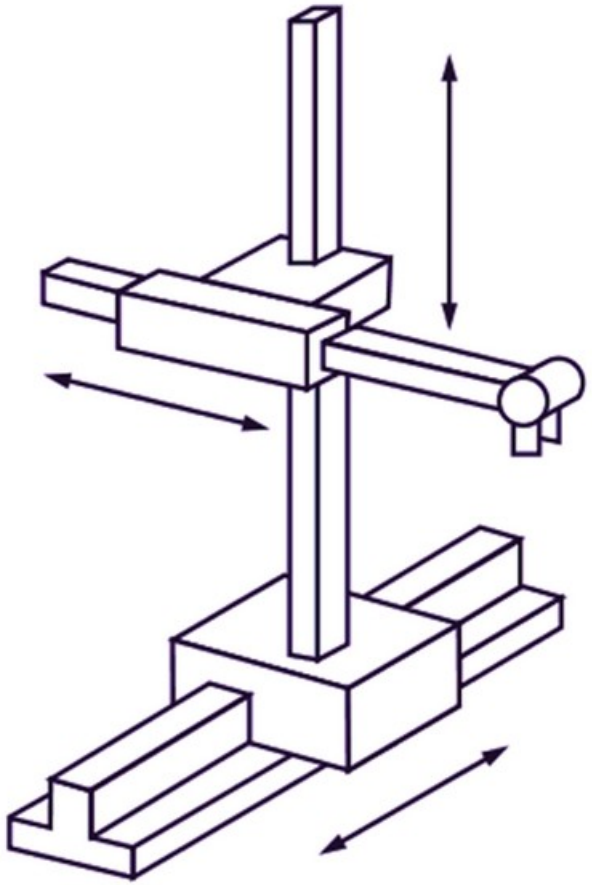
1. **Linear movement**: allows vertical lift to the arm because of one linear joint.
2. Two sliding movement: perpendicular to each other because of two orthogonal joint.

This configuration robot process in a rectangular workspace by three joints movement.

Robot Classification

Classification by Coordinate System

3. Cartesian Coordinate Configuration



Advantages

- Higher load carrying capacity
- Rigid structure, high degree of mechanical rigidity and accuracy
- High repeatability with least error at good speed.

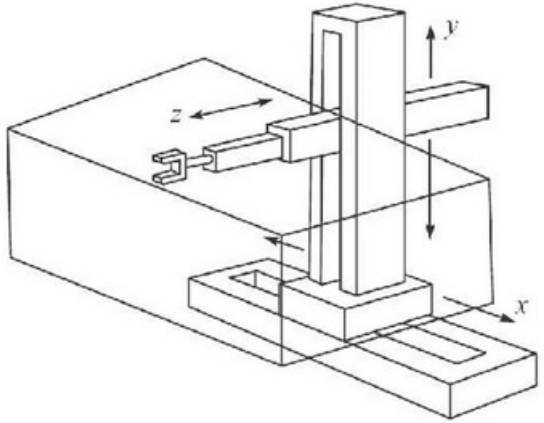
Limitations

- Has small and rectangular work envelope
- Has reduced flexibility

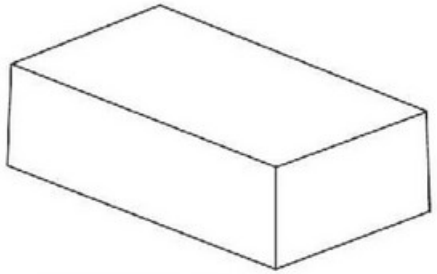
Applications: Inspection, assembly, machining operations, welding, finishing operations etc.

Ref: https://electricalworkbook.com/cartesian-robot/

3. Cartesian Coordinate Configuration



(a) Arm configuration

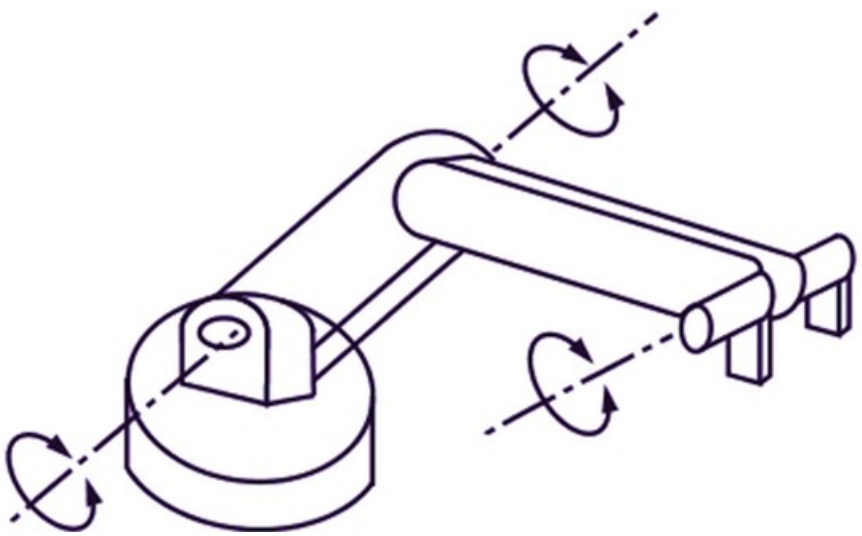


(b) Rectangular box

Robot Classification

Classification by Coordinate System

4. Jointed arm Configuration



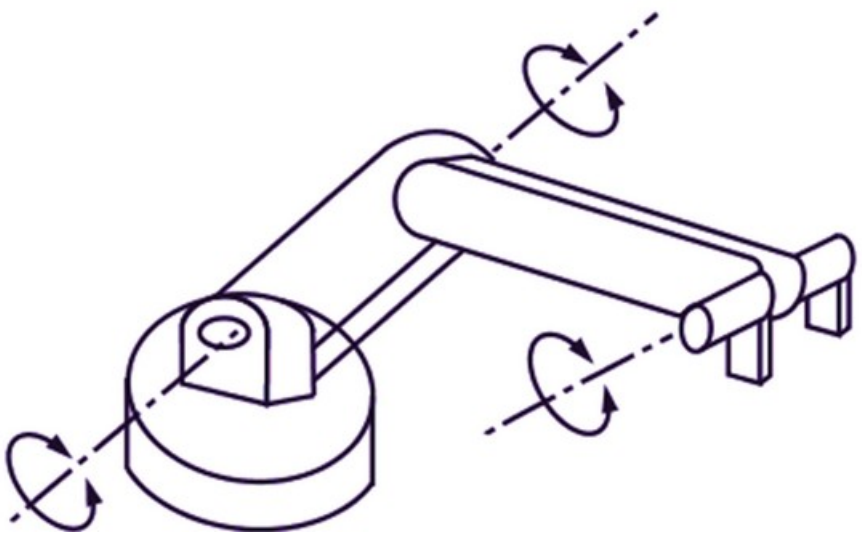
- Resembles to a human arm

1. **Rotary movement**: (vertical column that swivels about base) occurs around an axis (horizontal) parallel to the base because of twisting joint.
2. Rotary movement: at the top of the column about the shoulder joint (along the horizontal axis) because of one rotational joint.
3. Rotary movement at the output arm about the elbow joint (along horizontal axis) because of one rotational joint.

Robot Classification

Classification by Coordinate System

4. Jointed arm Configuration



Advantages

- Huge work volume
- Higher flexibility and quick in operation
- 2 rotational joints allows for higher reach from the base
- Provides reaching congested small opening without restrictions

Limitations

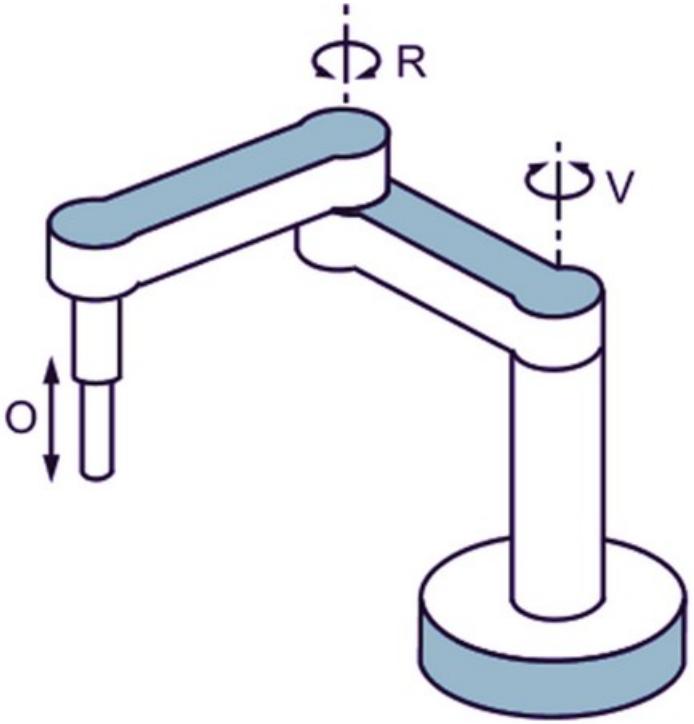
- Difficult operation procedure
- Plenty of components

Applications: spray painting, spot welding, arc welding etc.

Ref: https://electricalworkbook.com/jointed-arm-robot/

Robot
ion

SCARA (Selective Compliance Assembly Robot Arm)

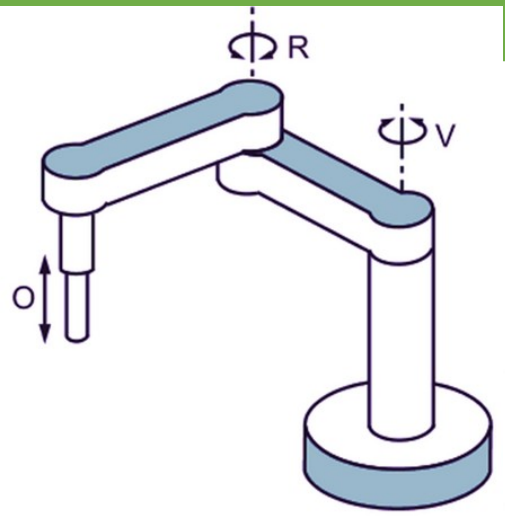


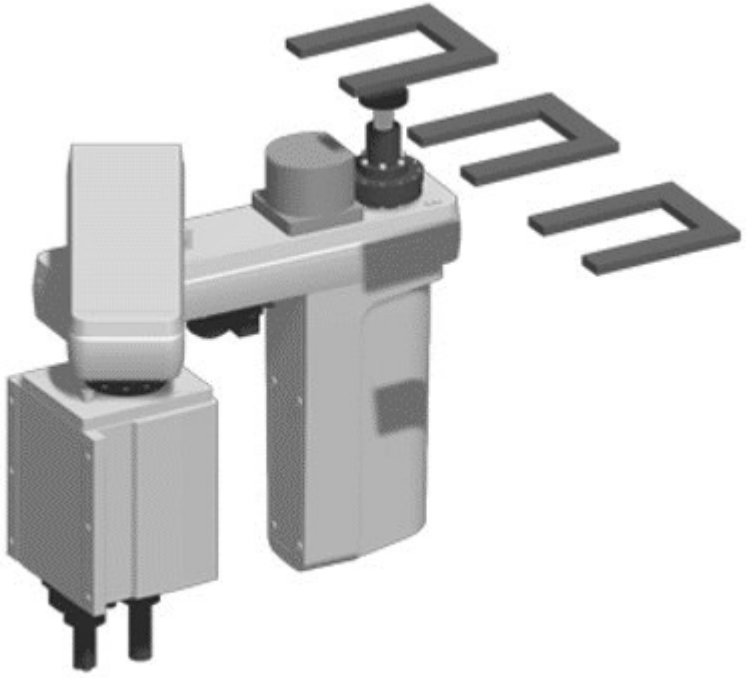
1. Linear movement: allows the arm to extend and retract because of one orthogonal joint
2. Rotary movement: at the top of the column about the shoulder joint (along vertical axis) because of one revolving joint.
3. Rotary movement at the output arm about the elbow joint (along vertical axis) because of one rotational joint.

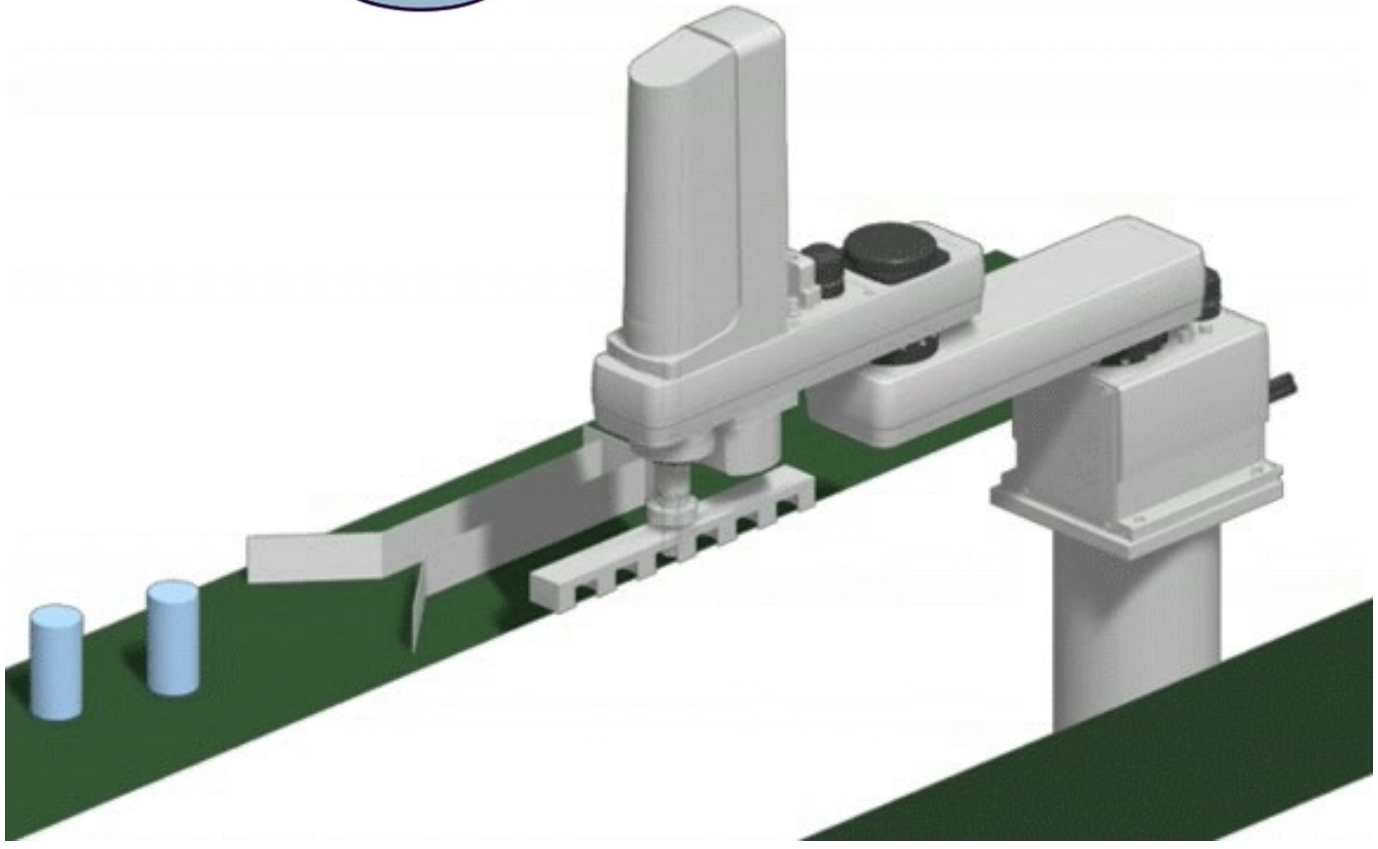
Applications: Perform insertion tasks (for assembly) in vertical direction

Ref: https://electricalworkbook.com/jointed-arm-robot/

SCARA (Selective Compliance Assembly Robot

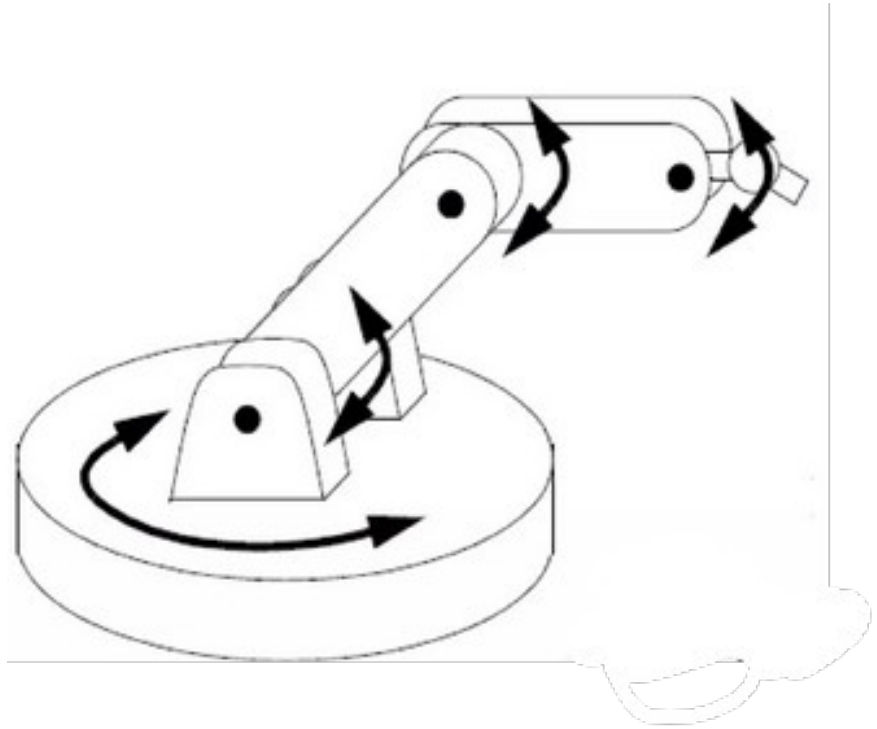




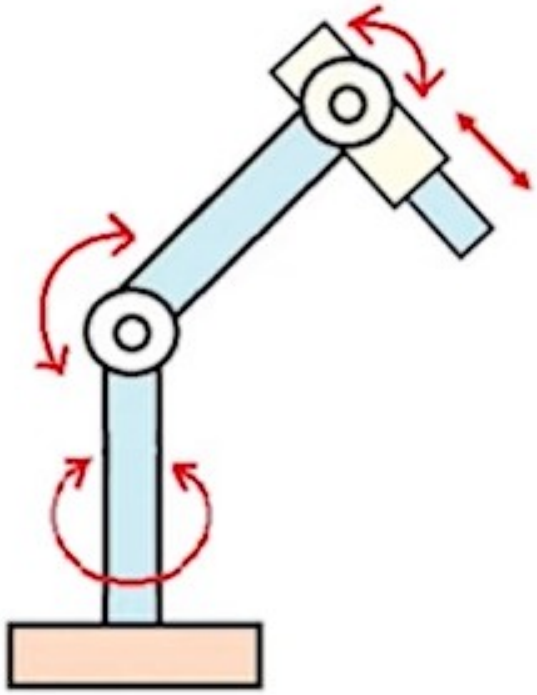


Robot Classification

Articulated / Anthropomorphic (3R)



- The articulate or jointed arm robot (Anthropomorphic arms) closely resembles Human arm
- The mechanical structure as three rotary joints which forms a polar coordinate system



Robot Classification

Classification by Control Method

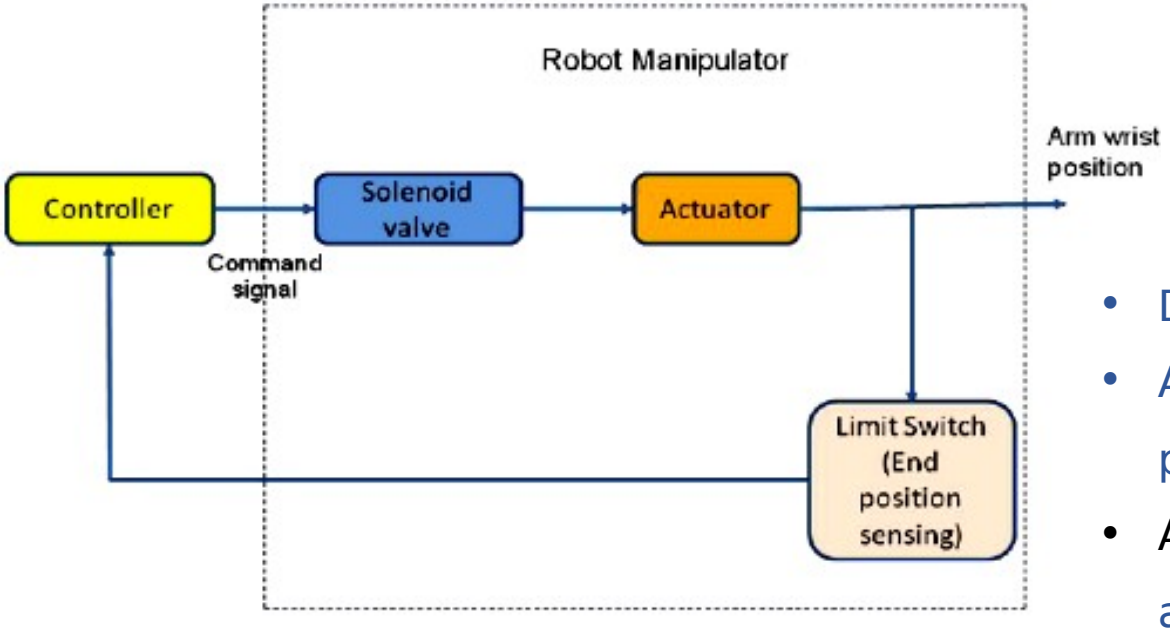
Classification based on the technique used to control the various axes of the robot.

1. Non-Servo controlled / limited-sequence robot
2. Servo controlled
3. Point to point servo-controlled robots
4. Continuous path servo-controlled robots

Classification by Control Method

Non-servo-controlled robots

- Also referred as limited sequence robots, end-point robots, pick & place robots.
- Robot are controlled by setting mechanical stops or limit switches to establish end points of travel of each joint.
- The mechanical setup to give the proper position.
- Sequence of stops serves as a basic programming approach rather than a computer intensive



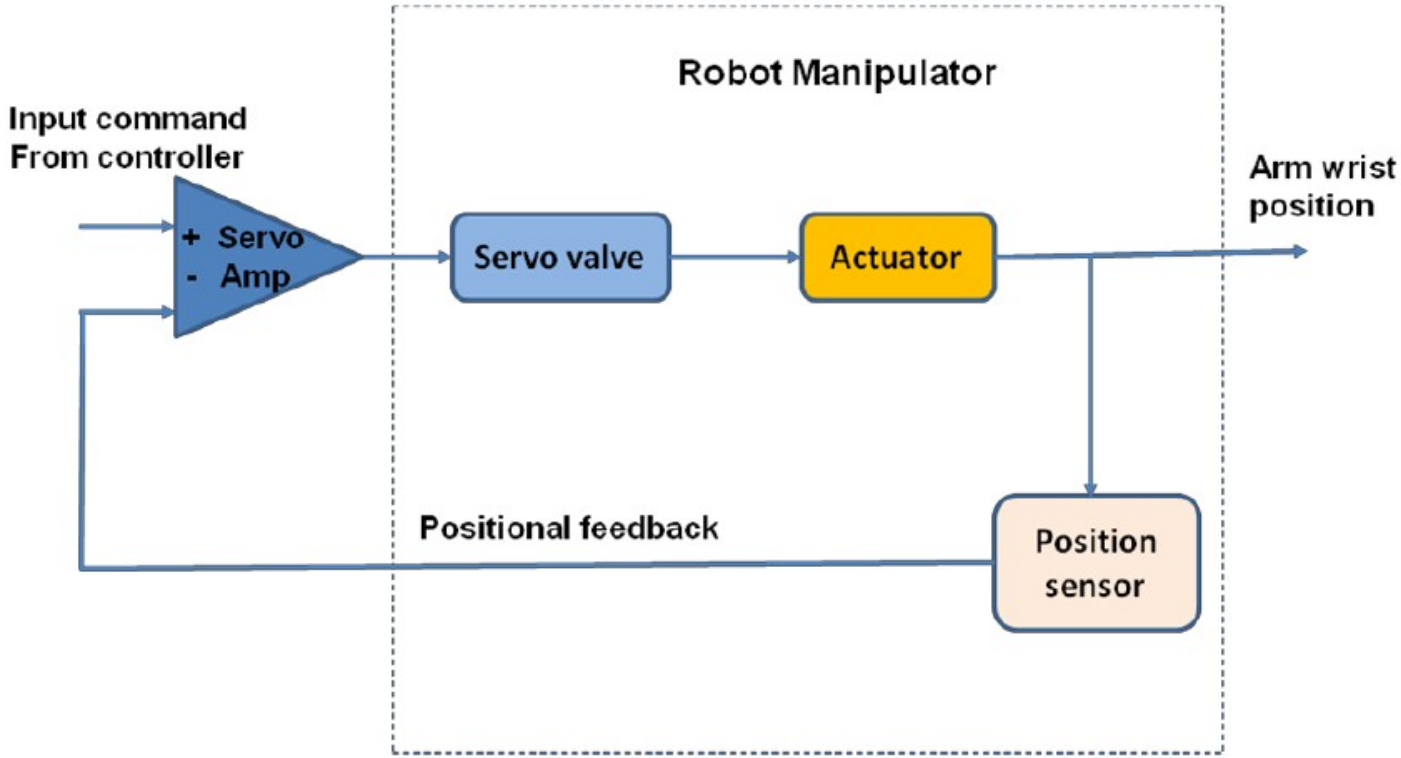
Non servo

- Drive signals are sent to the actuator via the solenoid valve.
- Actuator drives the wrist or end effector to the desired position.
- A signal through limit switch is sent back indicating that the arm has reached the position.

Classification by Control Method

Servo-controlled robots

- Reference signals are sent to the actuator via servo valve.
- Actuator moves its arm, wrist or finger to a current position.
- Continuous measurement is taken to estimate the error between the desired position and the current position
- Error signal is fed back continuously to monitor the position.
- As the error becomes zero, the desired location is achieved and the actuator stops moving
- Positional sensors are employed at the joints, wrist or suitable locations to feed back the positional information to the comparator



Positional Servo System

Classification by Control Method

Point-to-point servo-controlled robots

- Most robots today operate on a system called point-to-point control.
- Control is achieved by moving the robot to a specific location (point) during programming and recording the coordinates of the point into memory by pressing a button on the teach pendant.
- During the programming phase, all points are recorded in the order the robot must move to them.
- When the robot runs the program, it moves sequentially from point to point.
- When the robot reaches a point, it can energize or de-energize output signals to energize end effectors or send output signals that are used for interfacing to other equipment in the cell such as pneumatic cylinders that are used to move parts into location.

Classification by Control Method

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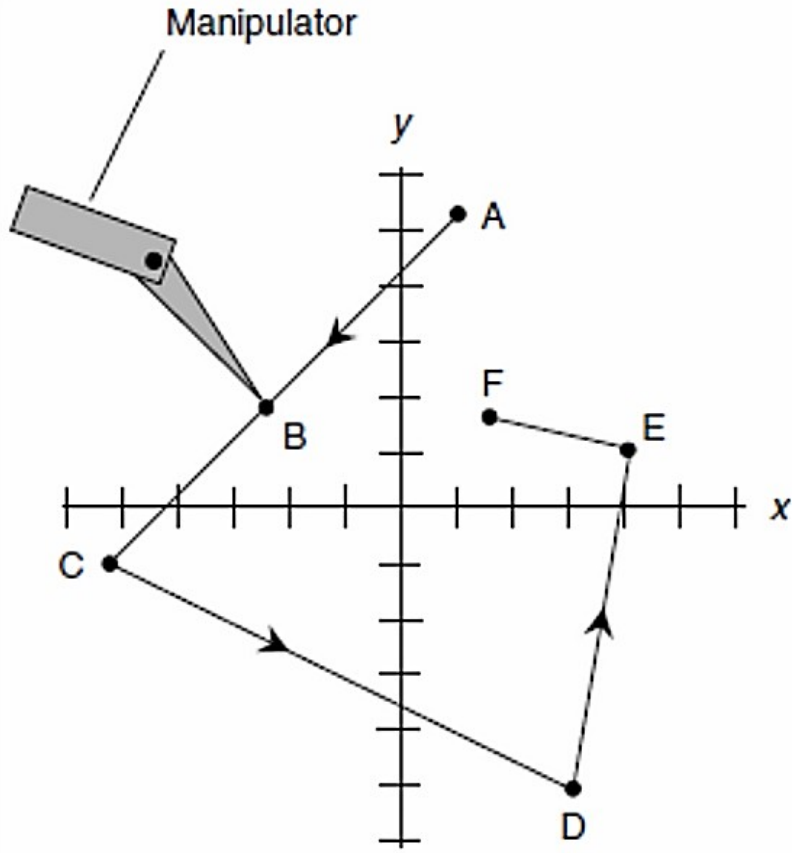
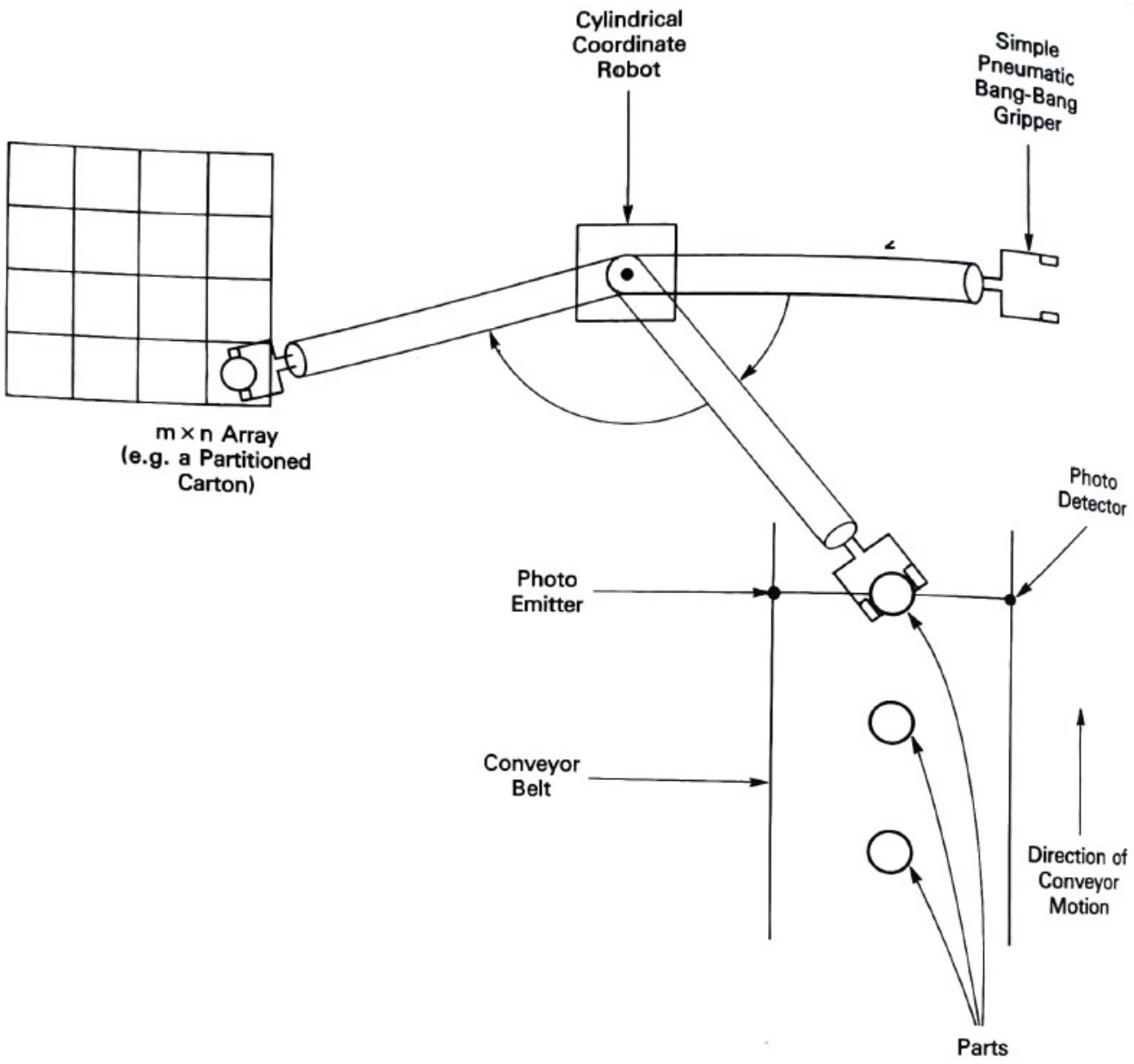


Point-to-point motion

Classification by Control Method



Point-to-point servo-controlled robots

- Use of a robot in a palletizing operation.
- When a part moves on a conveyor, and interrupts the light beam from a photo emitter, the controller commands the robot to acquire the part.
- This part is then moved to and placed in one of the empty locations in a partitioned carton.
- This process is repeated until all such locations are filled, the carton is removed from the loading station, an empty one replaces it, and the operation is repeated.

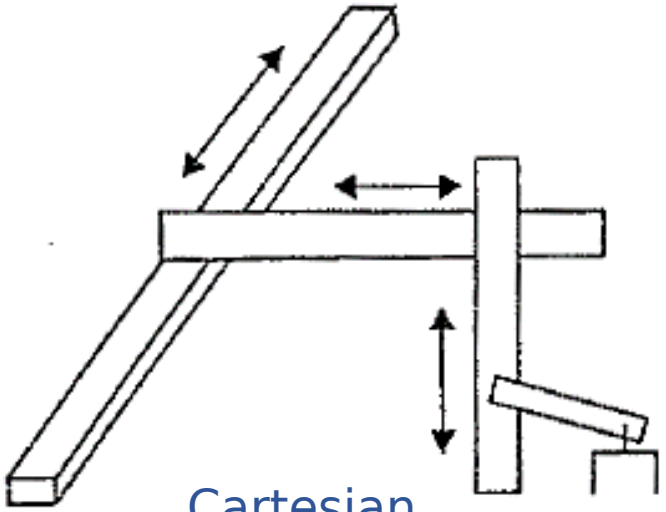
Classification by Control Method

Continuous path servo-controlled robots.

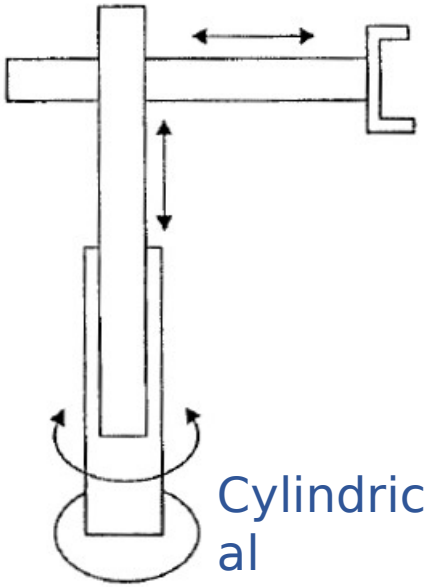
- Robots follow a complex path through space and possibly have the end of the arm move at high speeds.
- Examples of these applications include spray painting, polishing, grinding, and arc welding.
- This type of robot must follow a precise path when it's spray painting; each location in the path the robot takes to move from point to point is recorded during the programming phase of the project and replayed when the robot is in the run phase.

Advantages and Disadvantages

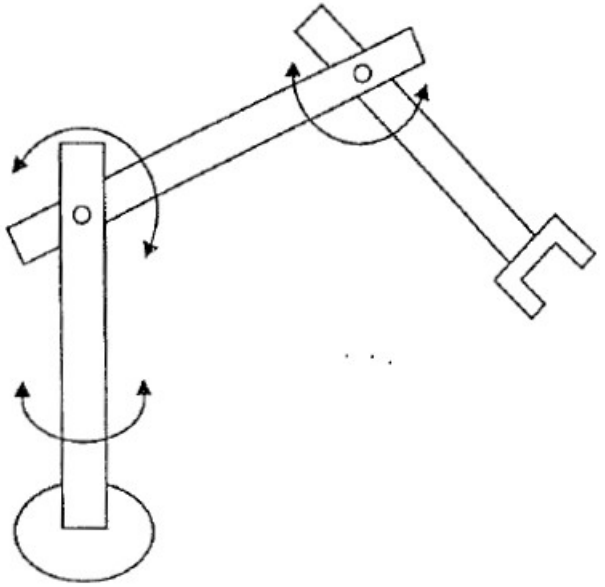
- This type of robot is easy to program because no special programming language is needed to get the robot to repeat the exact path it was taught.
- The drawback of this type of controller is that programming requires large amounts of memory to record the exact path and the speed during each part of the program.



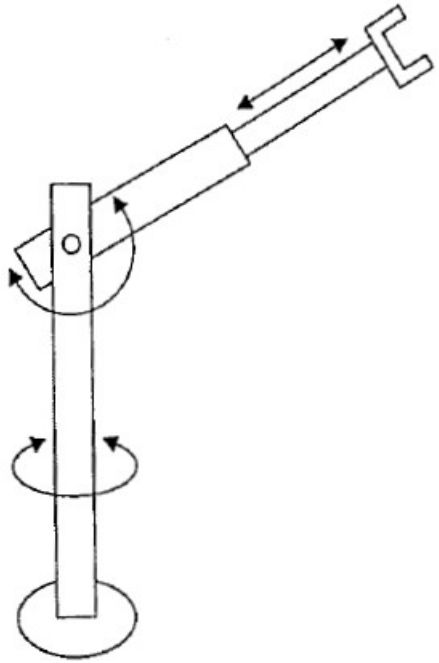
Cartesian



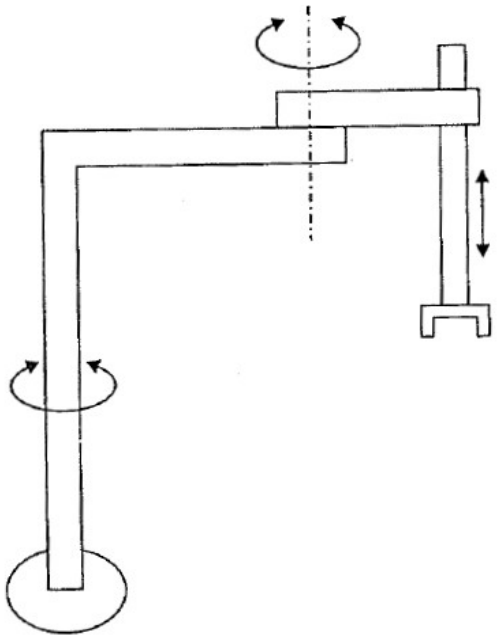
Cylindric
al



Articulated /
Anthropomorphic



Polar /
spherical



SCARA

Robot Specification

1. Repeatability

- Ability of a manipulator to return to a position in space where it had been previously.
- It is measured by going to that position in exactly the same way (over the same path, speed, payload, acceleration) no. of times.

2. Accuracy

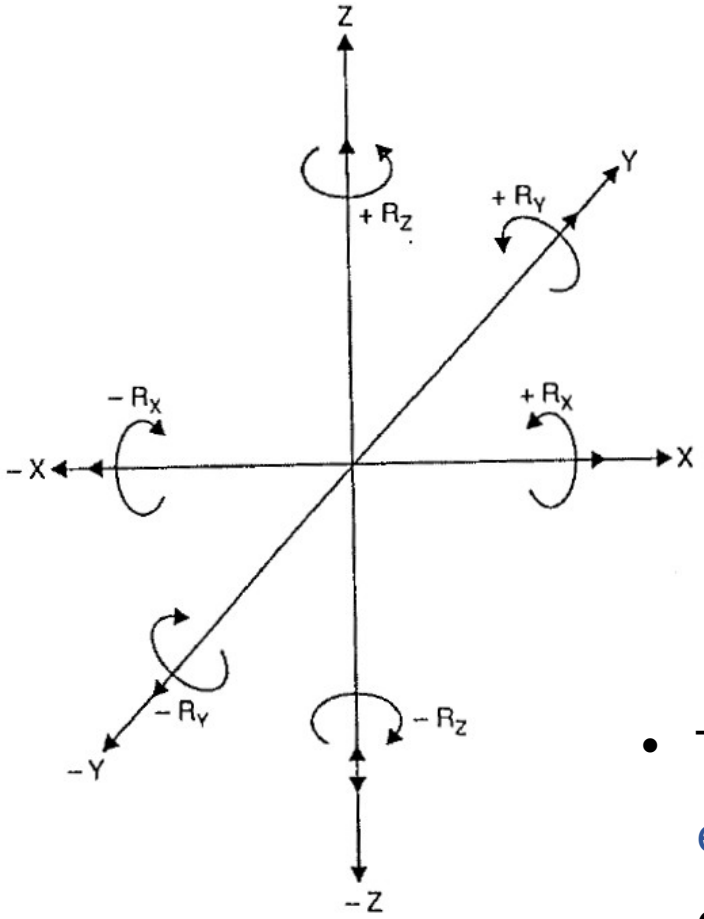
- The difference between the point a robot tries to achieve and the actual resultant position.
- The repeatability is the cycle-to-cycle variation of the manipulator's arm when aimed at the same point.

Brand	ABB
Model	CRB 1300-7/1.4
Axes	6
Reach	1400 mm
Payload	7 kg
Weight	79 kg
Repeatability	0.030 mm

Robot Specification

3. DOF (Degrees of Freedom)

- A body in 3D space can have 6 DOF (3 are Rotary & 3 are translatory).



- 6 DOF are positive & 6 DOF are negative.
- 3 DOF are translatory along +ve axis & 3 DOF are along –ve axis.

- The number of independent motions in which the end effector can move is defined by the number of axes of motion of the manipulator.

Brand	ABB
Model	CRB 1300-7/1.4
Axes	6
Reach	1400 mm
Payload	7 kg
Weight	79 kg
Repeatability	0.030 mm

Robot Specification

4. Payload

Rated load carrying capacity:

- Weight of the object or the tool held by the gripper, without affecting other functional characteristics.
- Overload leads to malfunctioning of the robot systems

5. Resolution

- The smallest increment of motion can be detected or controlled by the robotic control system.
- it depends on the distance between the tool centre point (TCP) and the joint axis.

Brand	ABB
Model	CRB 1300-7/1.4
Axes	6
Reach	1400 mm
Payload	7 kg
Weight	79 kg
Repeatability	0.030 mm

Robot Specification

6. Work Envelope

- A three-dimensional shape that defines the boundaries the robot manipulator can reach; also known as reach envelope.

7. Reach

- The maximum horizontal distance between the centre of the robot base to the end of its wrist.

Brand	ABB
Model	CRB 1300-7/1.4
Axes	6
Reach	1400 mm
Payload	7 kg
Weight	79 kg
Repeatability	0.030 mm

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Brand

Type

Axes

Reach

Payload

Brand	ABB
Model	CRB 1300-7/1.4
Axes	6
Reach	1400 mm
Payload	7 kg
Weight	79 kg
Repeatability	0.030 mm

ABB IRB 580/12S

Brand	ABB
Model	CRB 1300-10/1.15
Axes	6
Reach	1150 mm
Payload	10 kg
Weight	77 kg
Repeatability	0.023 mm

ABB IRB 580/16

Brand	ABB
Model	CRB 1300-11/0.9
Axes	6
Reach	900 mm
Payload	11 kg
Weight	75 kg
Repeatability	0.020 mm

ABB IRB 1100-4/0.58

Brand	ABB
Model	CRB 15000
Axes	6
Reach	950 mm
Payload	5 kg
Weight	27 kg
Repeatability	0.050 mm

ABB IRB 1100-4/0.475

Brand	ABB
Model	IRB 120-3/0.6
Axes	6
Reach	580 mm
Payload	3 kg
Weight	25 kg
Repeatability	0.010 mm

ABB IRB 1200-5/0.9

Brand	ABB
Model	IRB 140-6/0.8
Axes	6
Reach	810 mm
Payload	6 kg
Weight	98 kg
Repeatability	0.030 mm

ABB IRB 1200-7/0.7

Social Impact

1. Impact of Robotics on Direct Labour

- A robot performs multiple tasks, can be substituted for more than one human worker.
- Leading to the shift of direct labour to indirect labour activities
- Change in appointment strategy of new workers
- Set up of the work-space & operating robots needs education and training
- New workers need to have knowledge in installing, programming, inspecting, troubleshooting and maintenance.
- Skill and education standard of the operator has to be improvised
- Labor unions have to be taken into confidence through sufficient prior notice.
- Minimum careful displacement of workers, new technological adaption, training and guidance.

Social Impact

2. Professional Adjustment Impact

- With the advancement in automation, professional & semi-professional employees have to be familiar with & expertise in computer programming, robot maintenance optimization of processes etc.,
- Engineers from specialization in machine design, machine tool technology, control engineering, electronics & computer science can fulfil the needs of professionals in the robot industries.

Social Impact

3. Need for Education & Training

Present educational standards has to be revised to take care of

a) Highly educated force

b) Shortage of robot technicians

c) Deficiency in programmers

d) Well equipped laboratory facilities & instructors

e) Short fall in training institutes

f) Consultants to re-train the existing employees

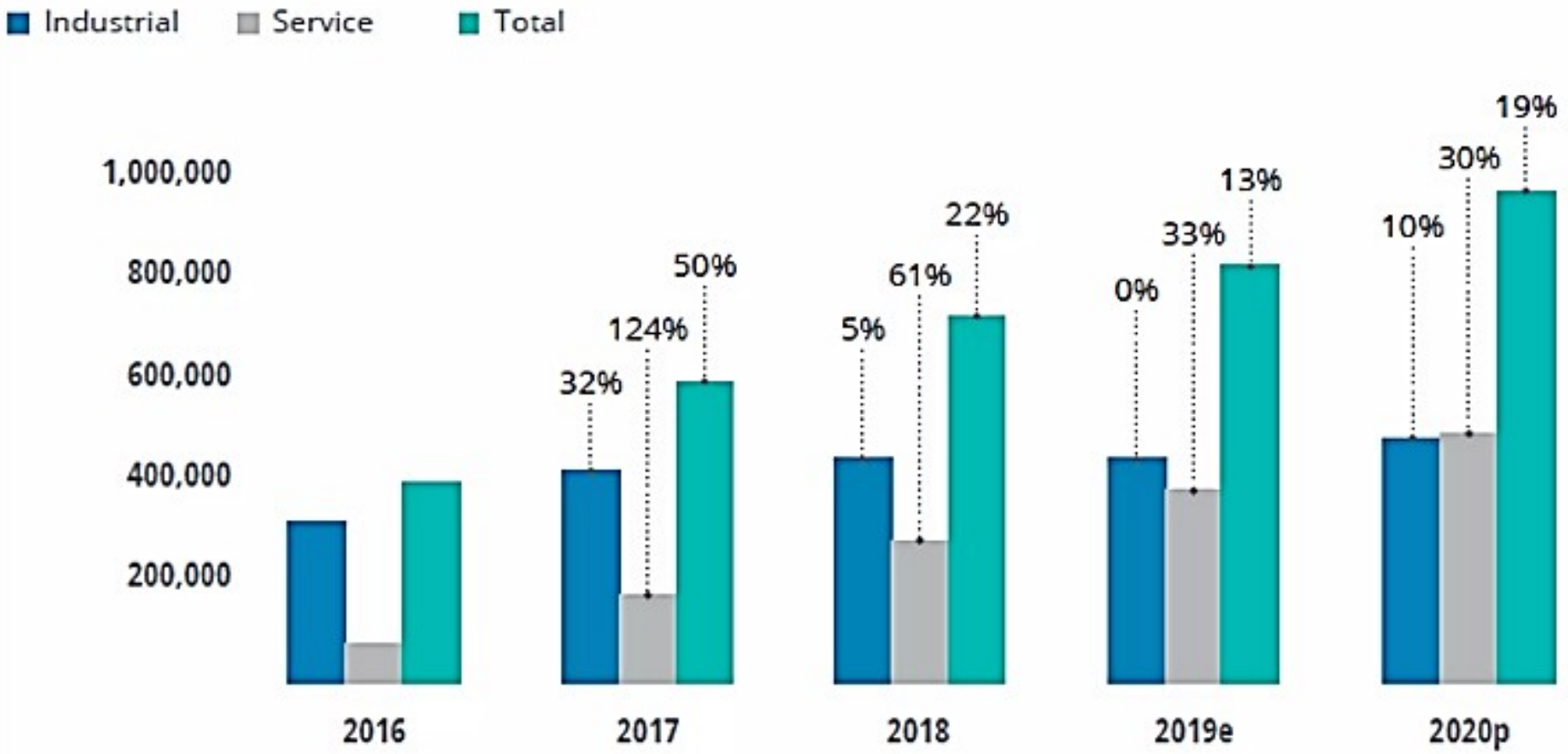
THE ROBOTICS MARKET AND THE FUTURE PROSPECTS

- Annual sales of robots have been growing worldwide
- Traditionally, it was the automotive industries that led the drive to robotize
- In the last decade, the growth of non-automotive robots has been higher than automotive robots.
- Surge in robotics investments: fall of robot prices, increased labour cost, increased accuracy, speed, versatility, shrinking workforce in several developed countries and ageing population

THE ROBOTICS MARKET AND THE FUTURE PROSPECTS

The professional service robot market, while smaller, is growing much faster than the industrial robot market

Annual global robot unit sales for enterprise use, 2016–2020



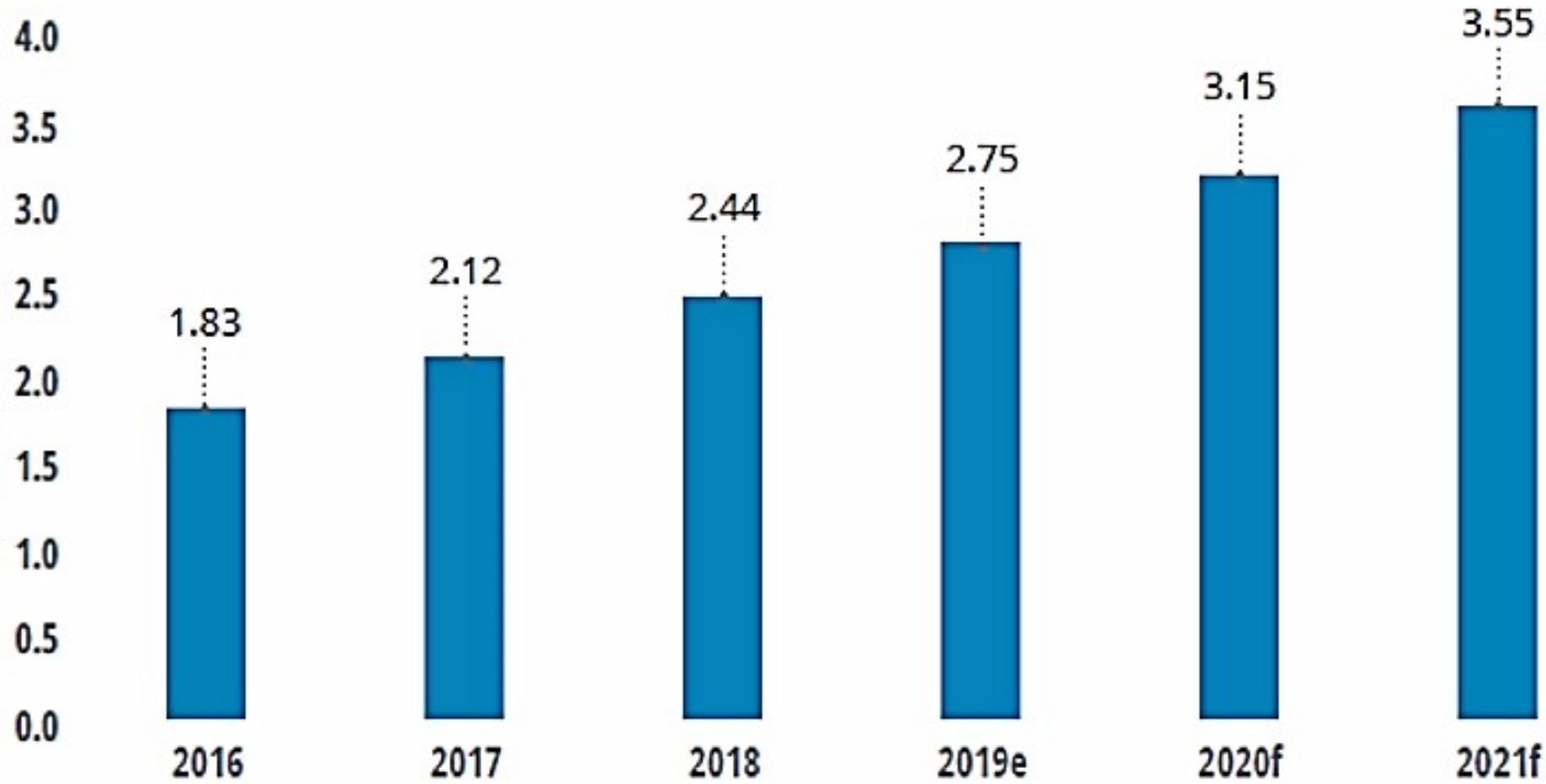
Note: The percentages above the columns denote annual growth rates.

Sources: IFR press conference presentation, Shanghai, September 18, 2019; Deloitte analysis and prediction for 2020.

THE ROBOTICS MARKET AND THE FUTURE PROSPECTS

Nearly four million industrial robots are expected to be in use by 2021

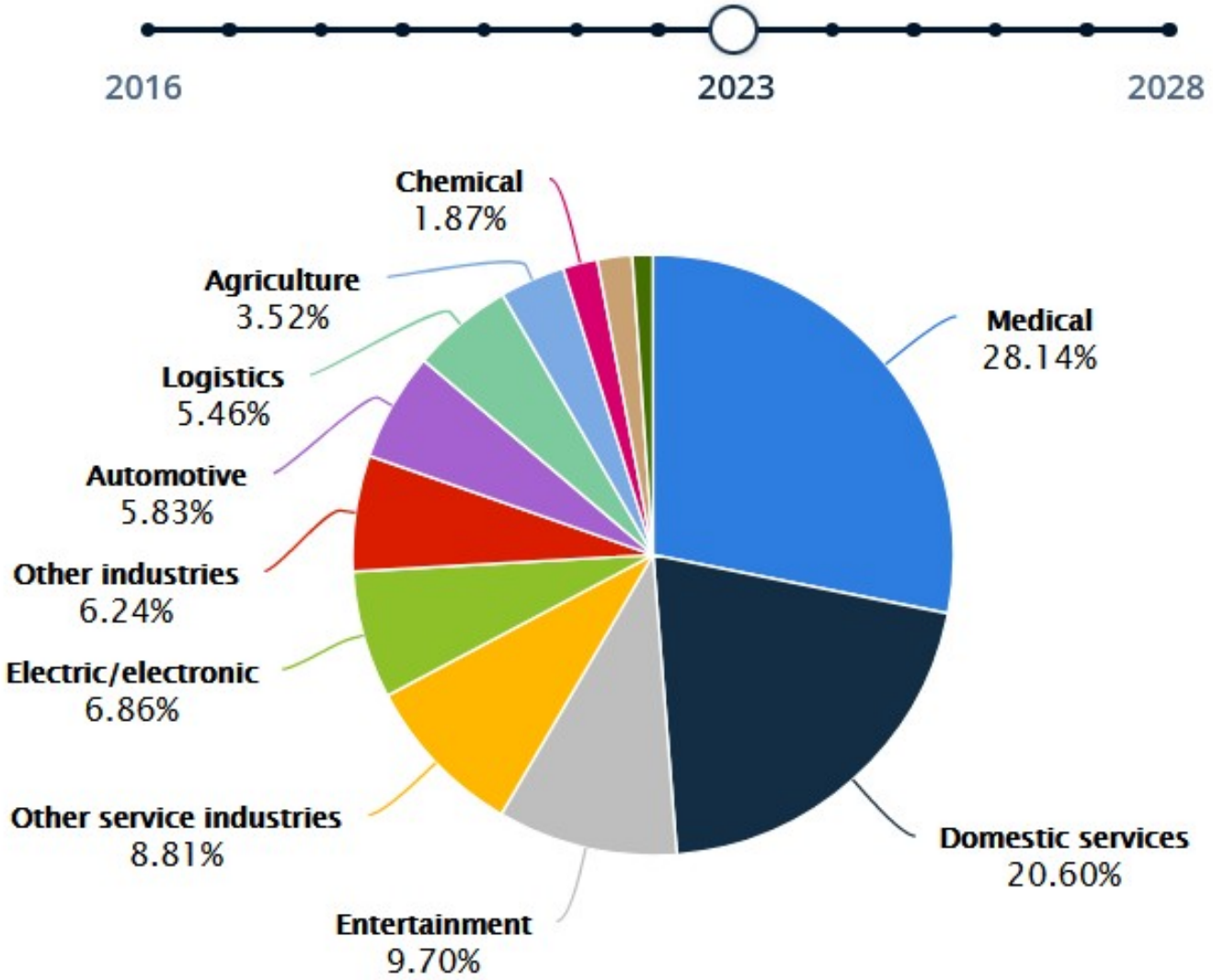
Annual global installed base of industrial robots, 2016–2021 (millions)



Source: IFR press conference presentation, Shanghai, September 18, 2019.

REVENUE INDUSTRY SHARE

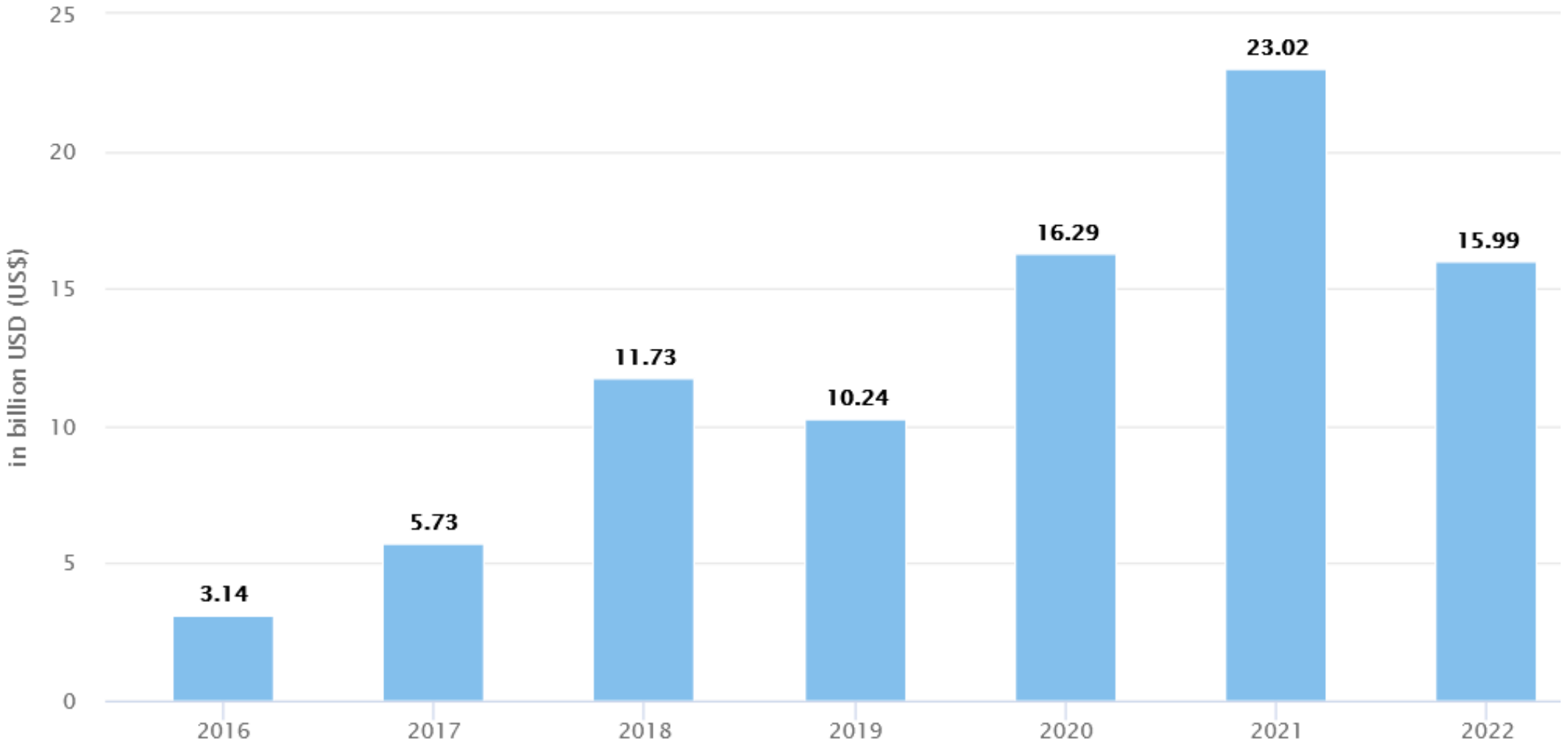
in percent



Most recent update: Aug 2023

https://www.statista.com/outlook/tmo/robotics/worldwide#volume

ROBOTICS INVESTMENT



Most recent update: Aug 2023

Source: Statista Market Insights

https://www.statista.com/outlook/tmo/robotics/worldwide#volume

Robot: Advantages & Disadvantages

Advantages of Robots

- Increased productivity, efficiency, quality, and consistency.
- Robots can’t get bored with their job, they can repeat the same task continuously.
- More accurate than humans.
- Robots can work in unsafe environments (chemical factories, radiation zone, etc.)

Disadvantages of Robots

- sical or environmental requirements like human needs
- Potential Job Losses
- Investment Costs
- Hiring Skilled Staff
- No analytical ability: Don’t have the power to think, analyze & create by taking information from surroundings
- Over-dependence on technology

Classification of Robots